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BRASSFOUNDERS' ALLOYS

A PRACTICAL HANDBOOK
CONTAINING MANY USEFUL TABLES,
NOTES AND DATA
FOR THE GUIDANCE OF
MANUFACTURERS AND TRADESMEN

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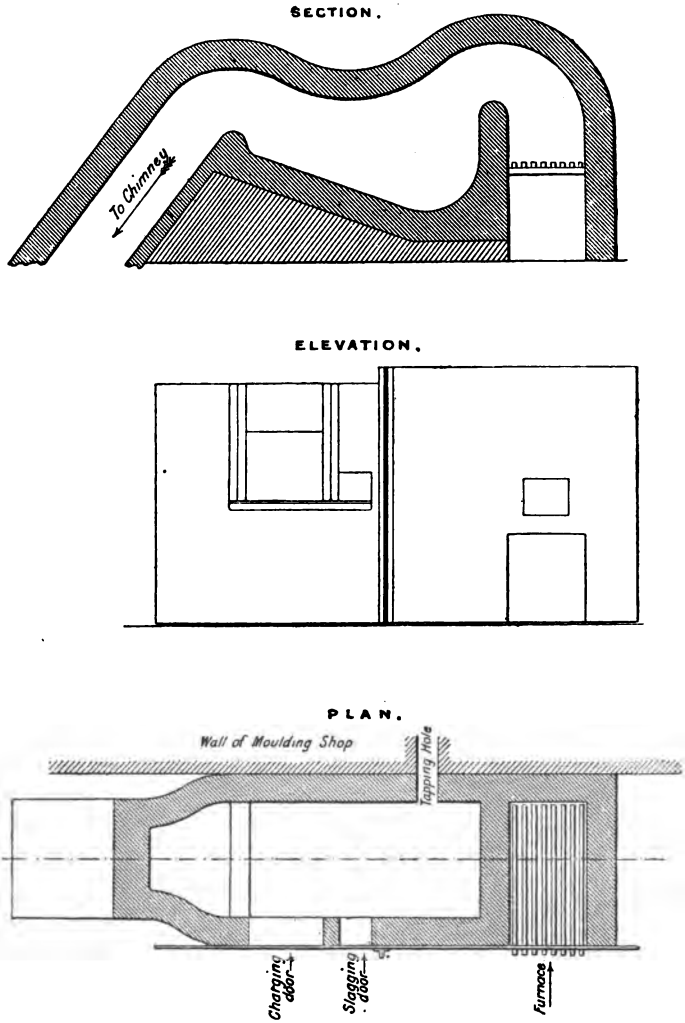

A REVERBERATORY FURNACE.

BRASSFOUNDERS' ALLOYS

A PRACTICAL HANDBOOK

CONTAINING

MANY USEFUL TABLES, NOTES AND DATA,
FOR THE GUIDANCE OF MANUFACTURERS
AND TRADESMEN

TOGETHER WITH SEVERAL ILLUSTRATIONS AND
DESCRIPTIONS OF APPROVED MODERN METHODS AND APPLIANCES
FOR MELTING AND MIXING THE ALLOYS

BY

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PREFACE.

It would be difficult to explain why so many books of a purely technical type have been written or compiled on the subject of alloys and metals generally, and so little attention has been given to the methods and formulæ that find favour in the foundry.

No such work, dealing with the practical points of alloying, has been presented yet, so far as we know; and hitherto, for want of such a *vade mecum*, brassfounders have had to struggle through a mass of technical details before they could arrive at an understanding of the few things of importance in the making of alloys.

This handbook is an attempt to meet the want; and being the accumulated experience and data gathered throughout an extensive responsible connection with the trade, it is calculated to present the practical features of manufacturing the alloys on a commercial basis.

By classifying the particular alloys required by the several branches of trade interested in them, and by tabulating only those mixtures which have been approved in practice, as well as by discussing freely what are understood to be the best methods of conducting the various operations, we hope to make these pages both interesting and profitable to all who are engaged in or connected with brassfounding.

J. F. B.

GLASGOW: 1901.

CONTENTS.

CHAPTER VI.

ILLUSTRATIONS.

BRASSFOUNDERS' ALLOYS.

INTRODUCTION.

It is not within the province of a mere handbook of alloys to give any elaborate description of the metals and their uses; therefore we make no attempt to grapple with their history, prior to the refining processes that all metals are more or less subject to before being brought into the market, neither do we purpose straining at the academic style common to the text-books on the subject; our aim being, briefly, to place before practical metal-workers a résumé of the operations involved in the manufacture of the various brassfounders' alloys, along with some carefully chosen tables of mixtures in present use.

Naturally, we leave the statement of the technical relations of metals and alloys, their physical formulæ, and the evolution of chemical equations, to those specially fitted to deal with these matters.

Various methods of classifying the metals have been adopted by the different scientists.

The chemists have grouped them according to their affinities and the character of the compounds they are capable of forming with the other elements, as oxides, sulphides, chlorides, carbonates, silicates, etc.; the physicists have divided them according to their densities or their relations to heat, light, electricity and magnetism; the metallurgists have separated them into classes and masses, "free" and "combined," noble and base metals, alkaline and earthy metals; and, as we have not touched on their relations to geometry, mechanics, mineralogy or other sciences, this does not by any means exhaust the list of possible divisions.

For our present purpose, however, it will suffice to keep before our minds the physical appearance and uses of the few metals commonly used in the manufacture of brassfounders' alloys; and, although these may be quite familiar to most people, we make a point of omitting no essential details on that account.

As already indicated, the metals, or as many of them as are found serviceable for brassfounders' alloys, will be considered only in their ultimate or commercial condition, so we proceed by giving the following table of established data respecting them. The atomic weights are those derived from the experiments of Stas. The other data are selected from various authorities; but, as in practice, a slight deviation from theory is to be expected, and, as no two similar pieces behave in precisely the same manner, the figures must be looked upon as being only approximately correct.

TABLE GIVING SPECIFIC GRAVITY, ATOMIC WEIGHTS, FUSING POINTS AND WEIGHT PER CUBIC FOOT OF THE USEFUL METALS.

Metals.	Symbol.	Specific Gravity.	Atomic Weight.	Fusing Point (deg. Fahr.)	Weight of one cubic ft. in lbs.
Aluminium (cast)	Al.	2·56	27·5	1157	160
Antimony . . .	Sb.	6·70	122·0	797	419
Arsenic . . .	As.	5·96	74·9	..	..
Bismuth . . .	Bi	9·82	210·0	516	614
Cadmium . . .	Cd.	8·45	111·6	599	528
Chromium . .	Cr.	8·69	52·4	above 4500	..
Cobalt . . .	Co.	8·90	58·6	2732	555
Copper . . .	Cu.	8·80	63·0	1929	549
Gold	Au.	19·25	196·2	2280	1203
Iron (cast) . .	Fe.	7·20	55·9	2737	450
„ (wrought) .	..	7·77	..	4000	486
„ (steel cast) .	..	7·90	..	3497	490
Lead	Pb.	11·40	206·4	626	710
Magnesium . .	Mg.	1·75	23·9	1428	109
Manganese . .	Mn.	8·03	54·8	2912	500
Mercury . . .	Hg.	13·60	199·8	39	849
Nickel . . .	Ni.	8·28	58·6	2643	516
Platinum . . .	Pl.	21·52	196·7	above 4000	1342
Silver	Ag.	10·50	107·6	1733	655
Tin	Sn.	7·40	117·8	450	462
Tungsten or Wolfram	W.	19·80	184·0	above 5000	1236
Zinc (cast) . .	Zn.	6·86	64·9	779	428
Metalloids.					
Phosphorus . .	P.	1·77	30·9	111	..
Silicon	Si.	2·50	28·0	..	..

CHAPTER I.

USES AND CHARACTERISTICS OF THE COMMON METALS.

Specialisation is the feature of the new century. We used to be content with "progress" for a watchword, and we strove hard to march in its line, but always in an empirical manner, which led us into many disagreeable experiences, and finally taught us that it was only by striking off into particular grooves —by becoming specialists—that the highest progress could be achieved. Scientific experts by engaging in special study and investigation have been able to diffuse principles of universal interest, and solve problems of immeasurable industrial advantage, thus helping on the general progress towards perfection in the several departments of science and art. Consequently, specialisation implies progress, and divisional labour has its place in the laboratory as well as in the workshop. Metallurgy as a science has developed surprisingly since the experts have ceased to be mere chemists knowing the *procès verbal* of the physical properties of metals. Manufacturers also are awakening to the

fact that many of the disturbing influences which mar their best efforts are due to prevalent misconceptions respecting the combined chemical composition and physical structure of materials.

Of course the physical aspects of a metal are of first importance to the engineer, and generally, if these prove satisfactory under the various tests, he reckons that any deviation from, or affinity to, chemical law in the material, may with safety be allowed to assert itself.

This it inevitably does, sometimes in a puzzling or unfortunate manner. An ordinary chemical analysis supplemented by the usual physical tests was at one time considered to give all the history of an alloy, but it is now recognised that metals and compounds may be incorporated in an alloy under conditions which would so change the arrangement of the constituents as to render it difficult, if not impossible, to determine the original state of combination or the ultimate condition of the product. Thus it happens that the proximate analysis of the chemist has no great value unless it is backed up with more specific information. In years past, there has been no lack of fanciful theories regarding the segregation, crystallisation and "fatigue" of metals, some of them based on insufficient data, derived from purely physical and chemical tests; but quite recently there has come into prominence, a new branch of metallurgical study called "metallography"—that is the microscopical examina-

tion of the structure of metals—which promises to eclipse the older methods.

Indeed, it has already been the means of revealing the causes of many peculiarities of metals and their alloys, which were formerly obscured, and confirming some notions concerning them which used to be looked upon as parabolic. The addition of this new science gives us a triple set of tests by which the properties of a metal can be judged, viz. the chemical, the physical, and the microscopical. The simplicity and exactness of the latter method of tracing the history and testing the value of a metal makes us wonder that it should have been overlooked for so long. We certainly owe much to the microscope as a scientific instrument already, and there is no saying to what extent it may yet be beneficial in applied metallurgy. At the opening of a new testing laboratory in Boston, U.S., Mr. Albert Sauveur made some interesting statements respecting the microscopical examination of metals. He expressed himself as follows:

"This new science which has been called 'microscopic metallography' has made remarkable progress in recent years, and it is confidently believed by those metallurgists who have kept in touch with its developments that it is destined eventually to stand side by side with the chemical analysis of metals in importance and usefulness. The two methods will complement each other. Concerning that all im-

portant factor, the heat treatment, which contributes so largely to the final properties of the metal, chemical analysis can tell us nothing. This is the domain which belongs to the microscope, and in which its usefulness will become more and more appreciated."

As the structure of a metal is the result of its chemical composition and the treatment which it has undergone, we can quite readily understand that by these microscopic tests we have a more exact means of ascertaining the various properties than by any mere physical test, or the usual proximate chemical analysis.

The accompanying illustration, which was embodied in a paper on the 'Microstructure of Bearing Metals,' read to the members of the Franklin Institute by Guilliam H. Clamer, is reproduced from the *Mechanical World* by kind permission of the proprietors.

We are aware of the existence of some fifty metals altogether, but up till now we have only found practical uses in the arts and industries for about a score, and for brass foundry purposes these can be further reduced to about ten.

Some of the metals are nothing more than chemical curiosities, and many of the metalloids—of which phosphorus, carbon, silicon and arsenic are good examples—are of much greater importance in the preparation of alloys than the purely metallic elements. A very

small addition of phosphorus in bronze, carbon or silicon in iron, or arsenic in lead, changes the structure and properties of these metals in a powerful manner, and it is in controlling these changes, within certain desirable limits, that the skill and intelligence of the founder is displayed.

Different metals require different treatment, according to their nature, or their affinity for certain other elements. Iron and nickel should be fused quickly, and at a high temperature, while lead or antimony should be fused only by a gentle heat. Some of the metals, such as iron with an excess of phosphorus or copper containing arsenic, are improved by being kept in a state of fusion for some time, but speaking generally, they should be poured as soon as they are fluid enough to cast the work on hand; this applies very specially to zinc, and alloys containing zinc.

Copper.—Touching the more useful metals, we take copper first, as being the synthetic base of most of the brassfounder's alloys. Copper is easily distinguished by its characteristic colour; indeed, copper and gold are the only metals possessing strikingly distinctive colours. Golden and copper colours are unmistakable; all the other metals vary in colour between the bluish-grey of lead and iron and the white of silver and platinum. Another unique property of copper is its high conductivity for electricity.

Although silver gives the maximum of conductivity,

copper is taken as the working standard. Fusion or heat treatment of any kind tends to lower the conductivity, and also the tenacity, of copper. About one-third of all the refined copper required by manufacturers is now produced electrolytically, on the same principle as electrotyping. The chief advantages of electrolytic copper refining over the old roasting methods are: the saving of gold and silver from the raw material; the higher conductivity and purity of the refined metal; and the cheapness of the process. The following table, giving the ratio of the cost of power to production in some popular electrolytic manufactures, is given by an expert in electro-chemistry: *

Metal.	E. H. P. Hours consumed in the production of 1 lb.	Cost of Power to produce 1 lb. with 1 E. H. P. at £5 per annum.
Aluminium Extraction	14·0	1·75 pence
Nickel ,,	1·0	0·13 ,,
Zinc ,,	1·0	0·13 ,,
Copper ,,	0·5	0·065 ,,
,, refining. . .	0·25	0·032 ,,

The copper of commerce is produced in a variety of forms to suit the purposes for which it is to be employed—as ingots for casting; sheets and billets for smith work; rods, bars and tubes for general

* *Mechanical World*, April 1, 1898.

fittings; wire for cables; etc. As the brassfounder is more immediately interested in the ingots, we notice in passing some of the best known brands of British manufacture. These are: R. T. crown—Rio Tinto; T. C.—Tharsis; J. B. S.—Bibby's; P. G. S.—Pascoe, Grenfell and Sons; H. H. S.—Hills, Henry and Son. These, along with the several brands of the celebrated Lake Superior mines, are all standard manufactures, suitable for making high-class alloys; after these we might mention a host of other brands which are sold as G.M.B.'s, but as their quality is neither regular nor reliable, we prefer to leave them severely alone. Professor A. Humboldt Sexton gives, in a recent work,* the following interesting series of analyses of refined copper, including the well-known Chili Bar, Tough, Best Selected, and Lake Superior Copper:

	Chili Bar.	Tough.	B.S.	Lake Superior.
Copper	98·50	99·15	99·90	99·83
Arsenic	0·10	0·50	0·05	trace
Antimony	trace	0·02	trace	nil
Lead	trace	trace	trace	·016
Iron	0·40	0·01	0·01	nil
Sulphur	1·00	nil	nil	nil
Nickel, cobalt	..	0·20	0·02	..
Silver	..	trace	trace	·026
Oxygen	..	0·02	·02	·15

* 'The Chemistry of Materials of Engineering.

Through the courtesy of the Broughton Copper Co., Ltd., we are able to give analyses of their Tough and Best Selected copper, which may be regarded as representative of high-class ingot copper:

	Tough Copper.	B. S. Copper.
Copper	99·25 %	99·50 %
Arsenic	0·35	0·04
Antimony	trace	nil
Lead	0·08	0·08
Bismuth	0·01	0·01

In addition to the constituents named, there are usually found minute traces of other matters, such as iron, nickel, silver, which, however, have no very injurious influence on the quality or behaviour of the copper. It will be noticed that the Best Selected copper is of similar composition as the Tough, excepting that, by being further refined, practically all the arsenic is driven off.

Many brassfounders prefer to buy in cuttings and short lengths of rolled copper, such as the Broughton Copper Co., or Muntz's Metal Co., make into tubes, bars and billets.

These manufactures are always of the highest grade, as the following analysis of copper tube, made by Professor Edwin T. Ball for Muntz's Metal Co., will show:

ANALYSIS OF COPPER TUBES.

Copper	99·860 %
Arsenic	0·013
Antimony	0·021
Bismuth	0·030
Lead	0·030
Iron	0·007
Silver	trace
Nickel	trace
Cobalt	nil
Oxygen and loss	0·039
Total	100·000 %

It is generally acknowledged that castings in pure copper are difficult to make, and as they are in ever-increasing demand, especially by electricians, it might be well to devote a few lines to the consideration of the best means of producing sound castings. The chief causes of failure are: (1) the difficulty of procuring copper free from impurities such as iron, arsenic or sulphur, which even in minute quantities have a pernicious influence; (2) the formation of cuprous oxide in the molten metal, causing unequal density and blow-holes; (3) on account of the viscous condition of the fluid metal, and an excessive contraction of volume taking place at the moment of cooling, whereby the metal is prevented from filling the mould completely. Some firms making a special line of copper castings for electrical fittings and tools for the manufacture of explosives, use electrically-deposited copper—guaranteed chemically pure—with very good results. The common practice in casting copper, how-

ever, is to add, whenever permissible, from 1 to $1\frac{1}{2}$ per cent. of either zinc or tin; lead is generally avoided in combination with copper alone, except for such castings as may be required to withstand the action of certain chemicals. For thin copper castings having sharp outlines, a small addition of phosphorus—about 5 in 1000—is advisable, as it deoxidises the metal, and increases its fluidity and elasticity. Manganese, like phosphorus, has a great affinity for oxygen, and it combines readily with the cuprous oxide formed in molten copper, thereby reducing the metal to a more uniform condition.

Probably the best method of obtaining homogeneous copper castings is to have them cast in chills, or in dry-sand moulds, adding from 1 to 5 per cent. of manganese at the time of casting. This can be quite conveniently done, as manganese-copper, containing up to 30 per cent. manganese, is one of the modern specialities in alloys. Castings made in this way are more indifferent to variations of temperature, slightly harder and tougher, and in every way easier worked, than by any other method that we know of.

Tin ranks next in importance on the list of metals useful for brassfounders' alloys. That it is a valuable metal is quite apparent to "the man in the street," for he speaks of so and so having "plenty of tin"—a slang phrase expressive of affluence, said to have originated on the Stock Exchange. We can readily believe this, as tin is a favourite metal with the stock-jobber; it

fluctuates freely in price, and a little of it (in scrip) goes a long way in a rising market. Tin was one of the earliest metals discovered, and from the time of the Romans, Cornwall has been one of the chief sources of supply. It is a brilliant white metal, very malleable, and of crystalline character; the so-called 'tin-cry' is caused by the friction of the crystals upon one another in bending a piece of the metal. The uses to which tin is put are almost innumerable; we need only mention the tinplate, pewter ware, and "tinning" industries, in conjunction with the bronze alloys, as typical examples.

The best brands of ingot or "block" tin are the Lamb and Flag of the South of England mines, or the standard produce of the Banca or Saxony mines. There is the same difficulty as with copper of obtaining the pure metal commercially. The following table shows a set of analyses given by Bruno-Kerl: *

	Banca.		British.		Peruvian.		Bohemian.	
	I.	II.	I.	II.	I.	II.	I.	II.
Tin . .	99·961	99·9	99·96	98·64	93·50	95·66	99·59	98·18
Iron . .	0·019	0·2	..	..	0·07	0·07	..	..
Lead . .	0·014	..	..	0·20	2·76	1·93	..	..
Copper .	0·006	..	0·24	0·16	..	..	0·406	1·60
Antimony	..	..	..	..	3·76	2·34	..	..

* Metalhuttenkunde, 1873.

Zinc in the metallic condition is a comparatively recent discovery; it is so volatile that it can only be obtained by distillation. Brass, i.e. the alloy of copper and zinc, used to be prepared by fusing the zinciferous ores *lapsis calaminaris* or the sulphide "black jack" and copper together. The variety of uses to which zinc is now applied arose from a discovery which was made in regard to its malleability. When cold it is very brittle; but when it is heated to within a certain range of temperature, from 210° to 310° F., it becomes quite malleable, and may be rolled into thin sheets, which are used principally for roofing houses and domestic utensils. Zinc alloys readily with copper, nickel or iron. When in the form of ingots or slabs, it receives the trade name of "spelter." There are two kinds of spelter, virgin and remelted; the latter is usually branded W.H., and may contain as much as 3 per cent. impurities, chiefly lead and iron. There is a large trade on the Continent in ornamental castings, statuettes, figures, vases and plaques in this metal. These are bronzed over and lacquered so as to resemble genuine bronzes.

Zinc owes its popularity to its permanency, being impervious to the effects of the weather. This reminds us of another notable zinc industry called "galvanising"; that is, the coating of iron with a layer of zinc to prevent it from oxidising, i.e. rusting. There is really no galvanic action evolved in uniting zinc and iron; it is a purely chemical process, due to

the formation of a zinc-iron alloy on the surface of the iron.

Lead is one of the most abundant metals, and, next to iron, perhaps it is the most useful. It was known to the ancients, and must have been brought into use at a very early date. It lends itself to a great variety of uses, and is made into sheets, pipes, paints, shot, etc. Being cheap, it is largely used in making up—or, rather, making down—brass founders' alloys, as, owing to the difference in value of lead from most of the other metals, there is a great temptation to use it systematically as an adulterant. The chief characteristics of lead are, its low melting point, malleability, and affinity for oxygen. It is nearly always combined with silver in the raw state, and many processes have been invented for the extraction of the silver.

Antimony owes its place among the metals useful for alloys to the powerful effect it has in hardening other metals, always, of course, at the expense of a proportionate amount of ductility. It is an extremely brittle, highly crystalline metal, of a silvery appearance.

In the foundry it is used principally for type metal, Britannia metal and anti-friction metal alloys, but as it combines freely with the negative elements, many uses have been found for it in the arts and in medicine. As nine-tenths of the brass-founders' alloys are compounded from these five metals, copper, tin, zinc, lead and antimony, we have noticed briefly their distinctive charac-

teristics and uses. When other metals are alloyed with any one or more of these the resulting compounds receive special names, as aluminium bronze, manganese bronze, bismuth bronze, silicon bronze, malleable bronze, etc. These will be dealt with under the heading of "Modern Alloys."

CHAPTER II.

SOME PECULIARITIES OF ALLOYS.

THE science of metallic alloys is still in embryo; and as it is only beginning to be taken in hand seriously and systematically by the professional workers, and the story of the fifty elements we call metals has yet to be told in a manner suited to the lay capacity, we cannot wonder if the ordinary individual—the artisan—should prove to be ill-informed in its technology. That there is a great scarcity of definite information regarding the making of alloys those who are directly engaged in the business know best. We are indebted, appropriately enough, to Germany and America—the lands of pure science and thorough-going practicalness—for having given prominence and publicity to the latest and most reliable information on the subject.

Mr. W. T. Brannt's book on 'The Metallic Alloys' * (partly a translation from the German) and Mr. Larkin's 'Brass and Ironfounder's Guide' have done much to

* Published by Henry Carey Baird & Co., 810 Walnut Street, Philadelphia.

promote and popularise useful and experimental research on many problems of absorbing interest to engineering manufacturers and the metal worker generally. It requires no great technical skill to determine the distinctive characteristics of a metal, viz. that it is a simple, fixed, opaque substance, fusible by heat, with high thermo-electrical conductivities, a degree of ductility, malleability, sonorousness and metallic lustre. But when we come to study the behaviour, or pursue the rationale of metals in combination, as ores, alloys or amalgams, we are confronted with a series of complex problems in chemistry, geometry, physics, statics and hydrostatics, which can only be explained by a progression of scientific deductions.

Time and again the savants have treated us to interesting data and erudite theories relating to the metals and their alloys which have been very helpful, but, despite all the costly and laborious experiments that have been made, a wide range of troublesome problems remain for solution, and a system of metallic alloys has yet to be formulated.

Theory and practice are often at variance in our industries, and the metal trade is no exception. We know by daily experience that when certain proportions of the useful metals are properly combined in a molten state we get an alloy of given requirements, but as there is a want of agreement amongst scientific authorities regarding the laws which govern the changes taking place in the physical and chemical

conditions of any such combination, we have not been able, so far, to unite the theory with the practice.

An alloy is usually defined as a mixture of two or more metals formed by fusion, but as there are no fixed proportions in which the metals must be combined to make an alloy, and the results often vary greatly from the mean of the constituent metals in colour, hardness, ductility, density and fusibility, it is still a matter of debate whether an alloy should be considered as a mixture or a compound. The term alloy is derived from the French *alliage*, and was at one time applied exclusively to mixtures of the baser metals with gold and silver. Any union of mercury with another metal is called an amalgam.

Dr. Muspratt observes: "It is evident that alloys, being composed of metallic bodies, will possess all the physical and chemical characteristics of metals, and it would almost seem that there is no department of the arts requiring the use of metals for which an alloy may not be prepared, possessing the requisite qualities when these are not found in the simple or original metals. The method of preparing them, however, has not yet been generalised, and has even, in not a few instances, failed, owing to the very meagre amount of information which has been gained upon the subject. The ten or dozen metals in use, if studied with care, are capable of producing several thousand alloys, but of these not more than fifty or sixty have been strictly examined,

so that it may be said that the art of alloying metals is yet in its infancy."

Every alloy, by the fact of its properties being different from those of the constituent, metals may be regarded as a new metal. The influence which certain metals exercise upon one another is very remarkable, as, for example, the peculiar characteristic of bismuth, which, although it lacks sonorousness, communicates a high degree of sonorousness to the alloy it forms with tin.

Other remarkable peculiarities of compounds containing bismuth are increased density and fusibility over the mean of the constituents. The standard fusible metal (Newton's)—bismuth 8, lead 5, tin 3—melts at 202° Fahr., although the fusion point calculated from the mean of its constituents is 514° Fahr. A familiar practical joke, which creates much amusement, is to have teaspoons made from this alloy; these dissolve in the act of stirring the hot liquid, to the astonishment of those guests who are unacquainted with this "marvel in metals."

The combination of copper and tin—two comparatively soft metals—in equal parts, furnishes another fine example of a complete change in the properties of metals by alloying. This alloy is the well-known "hardening" used in making anti-friction metals and bell-metal.

Many other examples, affording ample illustration of the existence of chemical affinity in metals sufficient

to produce new and unexpected qualities, could be given.

The most familiar of these are found in the iron group of metals—iron, nickel, manganese. Iron becomes steel and steel iron by the simple addition or subtraction of carbon. One per cent. of phosphorus makes steel quite unworkable for most purposes. Steelmakers, by adding three or four ounces of aluminium to the ton of molten steel, are now able to obtain uniformly solid ingots and improve the qualities of the steel, and manganese, as a deoxidising agent, sometimes takes the place of magnesium in casting nickel, or aluminium in casting steel and iron. Not many years ago silicon was looked upon by the ironfounder as one of his worst enemies, but now he reckons it to be about the most important element cast iron contains, its most prominent functions being the formation of graphitic carbon and the lowering of the saturation point of iron for carbon—or, in moulders' phraseology, a softener.

Nickel is refined and rendered homogeneous in Dr. Fleitmann's process by adding to the molten metal a small quantity of magnesium—about $\frac{1}{960}$!

In making what are called mitis castings—the invention of a Swede, named Ostberg—$\frac{5}{1000}$ of 1 per cent. of aluminium, in the form of a 7 or 8 per cent. alloy of cast iron, is sufficient to lower the fusing point of a charge of about 60 lbs. of wrought iron by some 500° Fahr., and the charge, now a combination of iron and aluminium, becomes extremely fluid, and can be

cast into the finest moulds, while the great difference between its temperature and its fusing point allows ample time for manipulating it without danger of its solidifying. These mitis castings are said to be from 30 to 50 per cent. stronger than the iron from which they are made, but, unfortunately, after hammering the metal returns to the fibrous condition, and to the strength of the original iron, thus proving that the strength of a metal depends altogether on its structure. Another inventor has been able to bring about a complete change in the structure of this metal and retain the increased strength by adding aluminium bronze instead of the pure aluminium. Castings from this peculiar mixture of pig iron, wrought iron and aluminium bronze, are the speciality of the Schmiedbarenguss Casting Company, Louisville, Ky., U.S.A. Two metals of totally different character may appear to be thoroughly mixed when in a molten state, but when solidifying they separate to a greater or less extent, and destroy the uniformity of the structure of the alloy, and when more than two metals of this nature are mixed the segregation is more pronounced, the constituents breaking up into several groups on cooling.

When manganese is combined with 6 or 7 per cent. of silicon, the alloy possesses the appearance of the preponderating metal, but differs much from it in chemical characteristics; it does not oxidise, even at a red heat, although manganese is probably the most

prone of all the metals to this action. Berzelius expressed the opinion that the presence of this small proportion of silicon is not sufficient to account for the total change of properties, and that there must exist in the compound or alloy, an allotropic modification of the metal, the alteration being effected or induced by the presence of the silicon at a temperature at which it would not occur with manganese alone.

Many of the useful alloys are also affected in a remarkable manner by minute additions of other elements. Thus common yellow brass is completely altered in character and colour, when a small per centage of manganese is combined with the alloy; when a small per centage of aluminium is present in a copper-zinc-lead, or cock metal alloy, segregation takes place and renders the metal quite unfit for casting; and an alloy of lead, tin and antimony, used for anti-friction metals, acquires an almost incredible increase of anti-frictional qualities by an extremely small admixture of bismuth—from 0·03 to 0·25—while a similar proportion of aluminium has the reverse effect. This latter statement is a fact, due to the investigations of Professor Goodman, who is an authority on the anti-friction subject. He points out * that some of the anti-friction alloys, though supposed to be the same, gave frictional results differing by as much as 100 per cent. Analysis of

* 'Proceedings of Institution of Mechanical Engineers,' 1895, page 289.

samples showed that the principal constituents were present in about the same proportions, but that there were differences in the amount of impurities present. Very minute quantities of some elements showed a marked effect on the friction—some increasing and others diminishing it, and further investigation proved that those elements of low atomic volume, atomic weight + specific gravity, increased the frictional resistance, whilst those of high atomic volume decreased it, provided that they were present in small and definite proportions. The addition of ·1 of aluminium, which has an atomic volume of 10·6, produced 30 per cent. increase in the frictional resistance, whilst the addition of bismuth which has an atomic volume of 21·1, immediately reduced the friction.

Alloys of metals whose specific gravity are dissimilar and whose melting points are far asunder, as copper-tin, copper-lead or aluminium-lead, are generally liable to liquation, that is, a separation of the metals composing the alloy into two or more compounds of unequal density and strength, thus destroying the homogeneity of the mixture. These are a few of the phenomena of alloys which are only known to founders by their results, beneficial or otherwise. While many theories have been advanced in endeavouring to explain the marvellous effects produced by such minute additions to metals or alloys, they are for the most part mere scientific speculations, the real causes still being shrouded in mystery. However, as the practical

value of such knowledge is not limited by the facts of experience, the worker in metals can best fulfil his mission by aiming at and labouring for practical results. Copper and zinc seem to unite in all proportions quite readily, some of them showing characteristic properties, indicative of chemical union, but uniform alloys of copper and tin are obtained with difficulty; the tin always has a tendency to liquate, or come to the surface in the process of cooling, causing tin spots or hard patches in the alloy. Copper and lead also combine only to a certain extent: 8 copper and 3 lead will hold all the lead, but that is about the limit for castings; 8 copper 1 lead is still ductile, and a very useful alloy for polished copper connections.

There are some important points of difference between the brass alloys and the bronzes, but for want of a proper system of designating alloys, such as chemists use for the negative compounds of the metals, the alloys of brass and bronze are often confounded.

Many of the so-called bronzes are actually brass with a small addition of some other element, say 2 per cent. manganese, iron or aluminium, which so alters the properties of the metal that it surpasses ordinary bronze in tensile strength, resistance to corrosion, elasticity and durability. The British Aluminium Company have adopted composite names for some of their light alloys, as "Wolframinium,"

"Romanium"—both terniary alloys,—but as these names give no indication of the copper content of the alloys, they are incomplete.

Of course there are difficulties—technical, commercial and æsthetic—in the way of composite names being used to indicate either the nature or composition of metallic alloys. If only two metals were required to be indicated, the thing would be simple enough, but to make some alloys there may be as many as four, five or six metals used; composite names for these are out of the question. Such a name for example as "Alumangophosphor bronze" (pointing to the presence of aluminium, manganese and phosphorus in a bronze alloy), would make an awkward mouthful, and, as the Yankees say, "just about fill the bill."

CHAPTER III.

COMMON METHODS OF MAKING ALLOYS.

In making alloys there is a recognised order in which the component metals should be melted, and also a particular temperature beyond which they should not be raised if they are to conform to the desired formula. Metals and alloys, and methods of reducing and combining them, have been made the subject of close investigation, and many practical, economical, and improved ways and means, have resulted therefrom.

The manufacture of brass alloys has slipped pretty much out of the hands of the brassmoulder of the present day. Thirty years ago he was a bit of a refiner as well as a moulder, and he served his apprenticeship to melting and mixing metals, as well as making castings from them. To-day that is all changed, and the moulder may be a better mechanic, but in most cases he lacks a proper acquaintance with the properties, behaviour, and constituents of the alloys that he has to work with. The advent of limited liability and joint stock companies has changed the old-world

rule-of-thumb methods for something more "slick"; and while it is true that the foundry apprentice of to-day has greater facilities for acquiring technical instruction in the art of making and mixing metals, it is also true that there never was a time when he had less opportunity for the practical exercise of such knowledge. The refiner has studied this branch of the business and made it his own, with the result that great strides have been made towards reducing the art of making brassfounders' alloys to something approaching a system.

The staple production of the brass refiner is known to the trade as ash metal. All kinds of brass skimmings, scrap, filings, sweepings, borings and ashes are collected, riddled, picked, ground, washed, remelted, and poured into ingots for this common quality of brass. The usual method of mixing metals in making brass alloys is what is called the direct method. This is accomplished by melting first in a plumbago crucible those metals which are most difficult to fuse, and adding in gradually, and with vigorous stirring, the more fusible or volatile metals shortly before pouring.

Zinc in copper-zinc alloys volatilises very rapidly, and should in no case be added in until about ten minutes before casting, otherwise the resulting alloy will not have the desired composition, and the loss in melting will be excessive. The average loss of brass melted in crucibles should not exceed from 2 per cent. to 3 per cent., but if melted in the reverberatory furnace,

the loss will be greater, 4 per cent. being a common proportion. The founder knows that he need not expect to get out of the crucible exactly what he puts into it, neither in gross weight nor yet in relative proportions; and where alloys are to be made to specification or subject to analysis, it is customary to make an allowance for loss in melting. The brass (copper-zinc alloys) require from 1½ per cent. to 2½ per cent. additional zinc to be added to the mixture, while the bronze (copper-tin alloys) require an additional ½ per cent. tin to compensate for loss through oxidation.

The following analysis, made by Dr. Clark, City Analyst, Glasgow, fully illustrates this point. In order to secure a contract, two castings, subject to various physical tests and chemical analysis, were required. The mixture stipulated was copper 86·5, tin 13·5. This alloy to be remelted, and proper allowance made for loss. This was done as specified. The original charge consisted of copper 86½ lbs., tin 14 lbs., the very best brands of copper and tin procurable being used, with the following result:

	Per cent.
Copper	86·33
Tin	13·35
Lead	trace
Zinc	—
Iron	0·10
Arsenic	0·30
	100·08

It is an axiom in the trade that any alloy is improved by remelting. This accounts for brass, in some form, being included in the making up of shop mixtures. Some firms remelt all their own borings and filings, keeping each kind by itself. By this means they have always a supply of their own particular alloys in ingots ready to be used in making and improving the new mixtures. Although most of the brassfounders' alloys are made by melting the metals into one another direct, that is not always the correct method.

Long ago the founder used to melt all the metals intended to be alloyed in separate crucibles; he then poured them into one another, agitating the mixture meanwhile to ensure intimate union. This method has now gone completely out of date, but a modification of it is still in use for making special bronze alloys and anti-friction metals; and as this is the best method of introducing known equivalents of copper and tin into an alloy, and it is possible to obtain a more homogeneous alloy by this method than by simply melting and mixing together the various ingredients, we think it deserves attention. An alloy is first prepared by melting a certain quantity of copper, and adding to it an equal quantity of tin. This is called "hardening or temper," and as every pound of the mixture contains ½ lb. of both copper and tin, it is a handy form for adding these metals into alloys, besides it gives a more uniform mixture. Another common application of this method is practised by some firms in making

German silver. The nickel is alloyed with half of the copper to be used in the alloy, and the zinc with the other half. The nickel-copper alloy is then remelted, and the copper-zinc alloys is stirred in gradually. Perhaps this is the most satisfactory method of obtaining sound castings in German silver.

It is a well-known fact that certain proportions of metals combine better than others, but it not unfrequently happens that an alloy of good composition is rendered practically useless because of improper treatment, either in melting or mixing; while an alloy of poorer composition can with careful manipulation be made to yield comparatively homogeneous metal. The unsatisfactory nature of many of the metals put into cocks and valves for steam or hydraulic pressure are more often due to unskilful melting or casting than to the poverty of the composition. Whether an alloy is made from new metals, or scrap alone, or a mixture of both, matters little if precautions are taken to overcome the varying tendencies of all metals to deteriorate in a state of fusion or by repeated melting.

Alloying in atomic proportions is a principle which is strongly advocated by many eminent scientists. Theoretically, nothing could be more simple. "It is known that the elements always combine with one another in certain quantities by weight, which are termed atomic weights (see page 3). By mixing the metals according to equivalent quantities, alloys of determined characteristic properties are, as a rule,

obtained. If these properties do not answer the demands made of the alloy, the object is frequently attained by taking two, three, or more equivalents of one metal. An exception to this rule is only made in certain cases, and especially where, according to experience, a very small quantity of a metal suffices considerably to change the properties of the alloy. It is then most suitable to prepare the mixtures serving for the experiment according to thousandths, and with every new experiment change the proportion between the separate metals a certain number of thousandths. For combining metals with non-metallic elements—for instance, with sulphur or with phosphorus—it is, however, not sufficient to choose the proportions according to thousandths, it being necessary to add these bodies according to ten thousandths." *

This is a theory respecting alloys which is seldom practised in the foundry, although it is held by chemists to be one of the best methods of making experiments in the preparation of new alloys. Certainly there are some notable instances of its successful application, as, for example, Lord Ross' speculum metal, which is an alloy of brilliant white lustre, and a true chemical compound, represented by the formula Cu4Sn, made from copper 126·4 parts, tin 58·9 parts, i.e. in atomic proportions.

We have another remarkable example in the common brass, Cu2Zn, so widely used in industrial pro-

* W. T. Brannt.

cesses, and well known by its full yellow colour, fine fibre, and great tenacity and ductility.

While we know that some people believe absolutely in the virtue of combining metals according to their atomic proportions, we also know that there are other practical methods in daily use on quite different lines. To the brassfounder, with scarcely any technical training, the law of combining metals according to their atomic proportions is a snare and a stumbling-block, and we think it better that he should go by the rule that he knows—even although it happens to be the much-maligned "rule of thumb"—rather than that he should grope about in a mist of atoms seeking to fathom the laws of chemical affinity and combining proportions.

The atomic theory, as applied to alloys or chemical compounds, is an abstract principle which has not yet been satisfactorily demonstrated.

Hooker puts it plainly when he says, "There is a large class of elements which invariably combine with each other in the proportion of one atom to one atom. There is a second class of elements which are prone to unite with two of these *monatomic* elements and are hence called *diatomic*, and are said to have two bonds, or units of affinity. Besides these monatomic and diatomic elements there are several other classes—the tri-, tetr-, pent- and hex-atomic—which combine respectively with three, four, five and six monatomic elements. This combining capacity, or

atom-fixing power, is generally believed to point to a real difference of chemical power; it has nothing to do with the atomic weights, nor with the combination by volume. The *atom-fixing* power of the elements is not a fixed quantity for each element, and the variations are ingeniously accounted for by supposing that in the lower powers the bonds are neutralised by self-saturation, or by combining with themselves. It scarcely ever happens that an element possessing an *even* atomicity can assume an *odd* atomicity, nor can the reverse take place; consequently, the elements are divided into two great classes, those of *even* atomicity, called artiads, and those of *odd* atomicity, called perissads. This whole subject of atomicity is a theory which is as yet only in its infancy, and is so replete with exceptions to the rule that the longer it is studied the more unsatisfactory it becomes."

The writer of a recent work on 'Modern Foundry Practice' complains that there is a great want of system in brass foundries. Well, as there are few trades offering so many facilities for the crank, or so many outlets for the experimental faddist, this is perfectly true. Seeing that there is no system, but only a series of experiments, to guide us in making alloys, it is quite natural that the intelligent tradesman should bring his experience—always a variable quantity—into play, in the endeavour to produce new alloys, and, if possible, "make a hit." Some of the most wonderful metals of modern times have been produced in this

way. Babbitt's Metal and Alexander Dick's "Delta" Metal were the outcome of an intimate knowledge of the needs of advanced engineering practice, combined with a grasp of the properties required to overtake them.

The following table reveals a system of composing alloys which (although we cannot recommend it) has the merit of novelty and simplicity:

THE "OLD HUNDRED" TABLE.

	Copper.	Tin.	Zinc.	Lead.	Anti-mony.	Alu-minium.	Phos-phorus.	Nickel.	Man-ganese.	Silicon.
Admiralty G.M.	88	10	2	..	..	..	..	..	..	..
Anti-acid "	88	2	..	10	..	..	..	..	..	..
Hydraulic "	88	10	..	..	..	..	..	..	..	2
Imitation "	88	..	10	..	2	..	..	..	..	..
Phos. Bronze .	88	10	..	..	..	..	2	..	..	..
Gilding " .	88	10	..	2	..	..	..	..	..	..
Alumn. " .	88	..	2	..	..	10	..	..	..	..
" " .	10	..	2	..	..	88	..	..	..	..
Brazing Metal	88	2	10	..	..	..	..	..	..	..
Plastic "	2	88	..	..	10	..	..	..	..	..
A.F. "	2	..	..	88	10	..	..	..	..	..
" "	2	10	88	..	..	..	..	..	..	..
Pattern "	10	2	88	..	..	..	..	..	..	..
German Silver	2	..	..	..	..	88	..	10	..	..
" "	10	88	..	..	..	..	..	..	2	..
Decorative castings	10	..	88	..	..	2	..	..	..	..
	2	..	10	..	..	88	..	..	..	..

This table was first introduced to our notice by a foundry manager, who had such a high opinion of the

Admiralty gun-metal proportions (88·10·2 copper, tin and zinc respectively), familiarly called "the old hundred," that he had all his mixtures made up in these numerical equivalents. Of course the man was a crank, and, like every other crank, could only progress along a prescribed line. A glance at the table, however, will show that there was some method in his madness, for he studied carefully the nature of the metals to be alloyed, and exercised considerable discretion in their selection. Besides, there is nothing shadowy about this system, as is the case with the atomic-fixing power theory. As the mixtures are thoroughly practicable, and good for the purposes stated, we think it not undeserving of notice.

The fact of this table opens up a question which it might be well to have discussed, namely, whether it is not possible to have a universal system of alloys, which would be applicable to the general requirements of engineering. Chemists, we know, are very fond of ten per cent. solutions, and, in the same way, some metallurgists seem to have a predilection for ten per cent. alloys. The standard gun-metal, aluminium bronze, phosphor bronze, anti-attrition metal, Britannia metal, brazing metal and tombac, may all be placed in this category. We believe it is quite possible to reduce the number of serviceable alloys, and determine which are the best for the various purposes of trade, and there is no doubt that a reduction, both in the number and constituents of alloys, would be a step in

the right direction. "A combination of many metals to one and the same alloy does not seem especially practical, since our knowledge of the alloys has scarcely reached such a point as to enable us to determine with absolute certainty how three metals in various proportions of mixture behave towards each other, and we are still less able to state with accuracy the behaviour of alloys in the preparation of which four, five, or even six metals are used. Besides, practical experience has shown such alloys to be frequently of no value, and are simply recommended by some persons in order to make a market for a new product." * So many manufacturers claim to have found the best methods and proportions for preparing certain alloys (and probably no two of them are made alike) that engineers are often at a loss to know which to select. Thus the success of a metal becomes more a question of catchy advertising rather than intrinsic merit. We acknowledge that economy and competition have been two important factors in the progress of engineering enterprise, but, at the same time, we are convinced that engineers would be consulting their own best interests if they demanded a guarantee of the constituents of materials, even although the initial cost were more. The whole secret of successful brassfounding lies in the making of suitable alloys at a profit, and the master or man who neglects the study of this branch of the business is criminally involved in any failure to accomplish that

* W. T. Brannt. 'Metallic Alloys.'

object. As a rule the market prices of the various metals rise and fall in sympathy with one another, but occasionally there is a "slump" or a "pool" in the higher-priced metals, like copper and tin, which have a bad effect on trade, and lead to the introduction of tricks and deceptive practices in order to make the manufacture of alloys profitable. Workmanship on a job can always be made to pay itself, but material may be employed which will destroy the best workmanship and end in heart-burning. If all the metals could be bought at, or near, the same price, the brassfounder would have few difficulties, as he would invariably make his castings from the very best alloys suited to the purpose for which they were to be used. This is the case with our own Admiralty, to whom money is a secondary consideration, and, because of this, the British Admiralty alloys have become the standard of excellence. The modern idea in producing anything for the market is to produce it as cheaply, and with as big a margin of profit, as possible. This is quite natural, but price and appearance are always the first considerations—serviceableness and utility come a long way after—and the foreman who can put away the greatest quantity of lead or zinc in making so-called gun-metal castings is the *rara-avis* so frequently advertised for as being "well up in mixtures." In most trades there are certain well-defined rules and recipes which have been formulated, and are to be observed in the progress of the business. Brassfounding, like most other

branches, has its trade secrets and formulæ. As a rule every firm has its own preserves in the matter of alloys, and every foreman has his own pet mixtures, which are invariably incomparable, or, at any rate, better than sombody else's. Some foremen pride themselves greatly on their knowledge of mixtures. They seem to think that they have a monopoly of correct alloys, and take pains to surround with a degree of mystery the particular ingredients, issuing their orders by a code, or in enigmatic form. Here is a rare Scotch sample. A foreman was asked by his furnace-man, in the presence of a third party, what mixture he would use for a particular job. The answer was, "Oh! mak' it twa o' our ain, ane o' paddy, an' a handfu' o' nails." Now the interpretation of this ludicrous recipe gives an average cock metal. "Our ain," stands for copper (the firm were copper-smiths); "paddy," is lead in the form of "pigs"; and the nails were old ships' sheathing nails; so that, if we were to try the mixture by avoirdupois measure, there would be two pounds of copper, one pound of lead, and from one to two pounds of yellow metal, according to the size of the "handfu'."

Notwithstanding the scores of "patent metals" and "finest alloys" that are in the market, the days of secrets in the metal trades are gone, for nothing can be hid from the chemist who cares to search, or the tradesman who cares to work intelligently for the object aimed at in any particular metal. Some of the saner business concerns with progressive instincts,

have recognised this fact, in modern times, by pursuing an enlightened policy, and issuing pamphlets and scientific brochures, regarding the metals which they produce, showing that they rely solely upon the excellence of their manufactures for business results. Of course there are still a few short-sighted firms left, who are afraid to give themselves away, and who are anxious to impress upon the public that their particular brand possesses talismanic properties which are to be found in no other.

CHAPTER IV.

BRASSFOUNDERS' ALLOYS.

BRASS is fabled to have been first accidentally formed at the Burning of Corinth, 146 B.C.; but articles of brass have been discovered in the Egyptian tombs, which prove it to have a much greater antiquity. Brass was known to the ancients as a valuable kind of copper. The yellow colour was looked upon as a natural quality, and was not supposed to indicate an alloy. Certain mines yielding this gold-coloured copper were much valued; but after a time it was discovered that by melting copper with a certain earth (calamine) the copper was changed in colour. The original method of manufacturing brass was by a process of cementation. Calamine brass was made by melting together copper, calamine and charcoal in clay crucibles, but as the result was always uncertain it was necessary to make a trial of the alloy before casting. The early specifications of brass usually gave instructions for preparing the alloy: we give two examples, one dated 1779, says, "Mix $\frac{4}{10}$ granulated copper with

$\frac{6}{10}$ lapsis calaminaris, or prepared 'black jack' (zinc blende) and with a proper quantity of charcoal, put the mixture in large closed clay pots in a furnace and melt, with the necessary heat." Another recipe of the same period says, "Take 3 parts of bean shot copper, 3 parts of calcined calamine and 2 parts of charcoal, and melt together." In 1781, James Emerson took out a patent for making brass by the direct admixture of copper and spelter, with or without the inclusion of calamine. In his specification for the patent, he gives a very interesting description of the process, which we quote.

"I take spelter in ingots and melt them down in an iron boiler; I then run the melted spelter through a ladle with holes in it, fixed over a tub of cold water, by which means the spelter is granulated or sholed, and is then fit for making brass on my plan. I then mix about 54 lbs. of copper shot, about 10 lbs. of calcined calamine ground fine, and about one bushel of ground charcoal together; I then put into a casting-pot a handful of the mixture, and upon it I put 3 lbs. of the sholed spelter; I then fill up the pot with the said mixture of copper shot, calcined calamine and ground charcoal. In the same manner I fill eight other pots, so that 54 lbs. of copper shot, 27 lbs. of sholed spelter, about 10 lbs. of calcined calamine, and about one bushel of ground charcoal, make a charge for one furnace containing nine pots for making brass on my plan. The pots being so filled are respectively put into the furnace, and about twelve hours

completes the process, and from this charge I have on the average 82 lbs. of pure fine brass, fit for making ingots, or casting for making battery ware, or brass latten; and my brass, made as aforesaid, is of a superior quality to any brass made from copper and calamine."

Ornamental Brasswork.

Castings, like all other articles of manufacture, are of two kinds, useful and ornamental. After design, colour is probably the most important feature of castings intended for ornament, as durability is the most prominent test of those which are for use. Alloys for ornamental brasswork are generally meant to resemble the precious metals gold or silver; and because of this it is important that the metals employed should be of the highest possible purity. Although gold is the universal standard of value, there are at present seventeen metals which are more costly—viz.: iridium, valued at £50 per pound troy; gallium, £75; rhodium, £85; osmium, £120; ruthenium, £200; palladium, about £216; barium, £280; didymium, £500; cerium, £525; yttrium, £630; strontium, £670; calcium, £700; glucinium, £820; lithium, £1080; zirconium, £1115; prubidium, £1400; vanadium, £1725.

Copper and zinc being the chief ingredients in the imitation metals, they are mostly modifications of brass with euphonious names, as "ormolu" and "argen-

tan." Pinchbeck, one of the oldest of this class, was named after its inventor, Christopher Pinchbeck, a London clockmaker, who died in 1732. It consisted of copper 4 parts and zinc 1 part. Dutch leaf gold, which is one of the most malleable alloys, is composed of 11 parts copper and 2 parts zinc. The average white brass or button metal is made from copper 43, zinc 57 parts. Statuary bronzes may be included amongst the ornamental castings, but they require to be durable, easily chiselled and gilded; with exposure they take on the beautiful brown or green colour known as "aerugo nobilis" (noble rust) or "patina." Gold adheres with great tenacity to all the bronze (copper-tin) alloys. The equestrian statue of the Emperor Marcus Aurelius, standing in front of the Capitol at Rome, still shows traces of the gold with which it was originally coated. The French and Italian founders are in high repute for monumental bronzes; but for originality of design, and skilful treatment of intricate ornamental castings the Japanese are still unequalled. The painstaking Indian metal worker has also gained an excellent reputation for all kinds of artistic brasswork—repoussé, engraved and cast. Biddery and Benares wares are well known, and have been extensively copied in modern times; but the greater part of these imitations are produced on the Continent by sheet-metal workers and die stampers, and are not to be compared with the genuine art of the East. It is well known that the French people

are extremely fond of jewellery, and it was but natural that they should foster and develop a trade in cheap and attractive imitations of the jeweller's art. As a nation they are admittedly clever and artistic, so we need not wonder if we hear now and then that the finish of certain styles of "Parisian" jewellery has deceived and excited the envy of better-informed people than the gaping bumpkin at the country fair.

Hitherto we, in this country, have been content to accept our quota of these baubles without a thought of entering seriously into competition with our continental neighbours. Artistic taste in British and American manufactures has been directed more towards architectural embellishment or home decoration than personal adornment.

Some fourteen years ago an American discovered a beautiful alloy, which has been most successfully applied as a substitute for gold. It is composed of copper 100 parts, zinc 17 parts, magnesia 6 parts, tartar of commerce 9 parts, sal-ammoniac 6·6 parts, and quicklime 1·6 parts.

The copper is first melted; then the lime, magnesia, sal-ammoniac and tartar are added, a little at a time, and the whole briskly stirred for about half-an-hour, so as to mix thoroughly, after which the zinc is thrown on the surface in small grains, and fusion kept up for another half hour, when the dross is skimmed off, and the alloy poured out ready for use. It is quite malleable and ductile, and may be drawn, stamped,

chased, beaten into powder or into leaves like gold-leaf, in all of which conditions it is not distinguishable from gold, even by good judges, except by its inferior weight.

German silver has come into very extensive use for ornamental and electrical purposes. In one sense it may be considered as brass with an addition of nickel, the amount varying from 15 per cent. to 25 per cent., according to quality. The nickel gives to the alloy a white colour, increased strength, hardness and power to resist acids—all valuable qualities. The average composition of German silver for casting is nickel 1 part, zinc 1 part, and copper 3 parts; but all these substances should be of the purest quality obtainable, as quite a small amount of certain impurities has a very injurious influence on the properties of the alloy.

The refractory nature of nickel, and the difficulty of obtaining the component metals free from arsenic and antimony, are the causes of the sickly gold-yellow colour of some German silver ware. German silver, if properly prepared from pure metals, will equal in whiteness the best silver, and will not tarnish.

While the alloy is essentially a mixture of copper, zinc and nickel, other metals may be added within certain limits with good results; from 2 per cent. to 3 per cent. iron gives increased hardness and whiteness, the same proportions of lead or manganese are helpful in producing sound castings, while a like quantity of tin adds to the brilliancy of polish obtain-

able. Neither the iron nor the manganese should be added in by the direct method; the iron is best alloyed with a portion of the zinc, and the manganese with copper, before being introduced into the German silver alloy. In making German silver, or complex alloys containing nickel, it is customary to first alloy the nickel with one-half of the copper, and the zinc with the other half. The nickel-copper alloy is then melted, and the copper-zinc alloy added in. Another method, which is probably as good and certainly more economical, is practised by some makers in Germany. The copper and nickel to be used are divided each into three equal parts. A layer of copper is placed upon the bottom of the crucible, upon this a layer of small coke, upon this a layer of nickel, upon this again a layer of coke; begin again with the copper, and continue the process until all the copper and nickel for the alloy are charged. The crucible is finally covered with a layer of charcoal powder, and the contents melted down as quickly as possible. In introducing the zinc, care must be taken to keep the surface of the melted metal covered with charcoal to prevent volatilisation of zinc. Nickel belongs to the iron group of metals, and it will be observed that the above treatment is similar to the orthodox method of melting iron.

Under the name of "maillechort," a German silver, containing about 15 per cent. nickel and a small proportion of iron, has been used as the basis of some electro-silver ware.

MIXTURES FOR ORNAMENTAL BRASSWORK IN WHITE AND GOLD.

	Copper.	Zinc.	Tin.	Nickel.	Lead.
White brass (soft) . . .	10	80	10	..	..
„ „ (hard) . . .	45	55	..	..	..
Birmingham platinum . .	43	57	..	..	..
Standard German silver—					
I.	50	25	..	25	..
II.	60	18	..	22	..
III.	60	20	..	20	..
Good casting	60	19	..	19	2
„ polish	59	27	2	12	..
English	62	25	..	13	..
Parisian	60	17	..	23	..
By D'Arcet	50	30	..	20	..
„ Frick	53·39	13	..	17·4	..
"Castle" brand . . .	56	24	2	18	..
"Crown" „ . . .	53	25	3	17	2
"Arguzoid"	56	23	4	14	3
"Argitan"	50	22	6	20	2
For heavy castings . .	42	36	..	20	2
„ electrical castings .	54	30	..	16	..
"Silveroid"	57	25	..	16	2
"Silverette"	2	..	2	2	Aluminium. 94
Dipping metal	16	6	..	..	..
Brilliant dipping metal . .	71	28	1	..	..
Gilding metal	80	20	..	..	..
Pinchbeck	88	12	..	..	..
Tombac (English) . . .	86	14	..	..	..
„ (German) . . .	85	15	..	..	..
"Chrysorin"	100	51	..	..	..
Gold bronze	90	3	7	..	..
Mannheim gold	83·7	9·3	7	..	..
"Similor".	89·8	9·6	0·6	..	..
"Ormolu".	58·3	25·3	16·7	..	..
"Talmi" gold	90	9	1	..	..
Indian „	95	2	..	3	Platinum.
Cooper's „	13	..	..	..	3
White platinum bronze . .	Yellow brass 65			30	5

According to Trabuk of Nimes, a beautiful white alloy, which resists the action of vegetable acids, and may serve as a substitute for German silver, is obtained by melting together 87·5 parts of copper, 5·5 parts nickel, 5 parts antimony, 2 parts bismuth. An alloy of copper, and from 20 per cent. to 25 per cent. nickel, is a favourite metal with some countries for coinage. For imitation silver-ware, Pelouze recommends copper 50, nickel 50, or copper 66·6, nickel 33·4. Chinese Paçkfong or white copper consists, according to analysis of Dr. Fyfe, of 40·4 parts copper, 31·6 parts nickel, 25·4 parts zinc, and 2·6 parts iron.

Shop mixtures are generally made up in parts—preferably in aliquots of avoirdupois numbers—to save trouble in calculating the various proportions, and to avoid having to convert them from other relative measures. We have lately been told that the coming of the kilogramme is at hand, but although the metric system has been legalised in this country, it is seldom used, except for technical or commercial reasons. The adoption of a universal standard of values would undoubtedly simplify many of the transactions of trade, but as we are still condemned to handle the old-fashioned lbs., qrs., and cwts., we give the shop mixtures in their original form, unless they can be conveniently stated in whole numbers centesimally. Another feature of shop mixtures is that they nearly always contain a quantity of some kind of mixed metal suited to the purpose of the

alloy. Some shops even go to the trouble of making up a special alloy for this purpose, which they call "mixing metal." Here is the composition of a mixing metal used in a large railway shop: copper 80, tin 14, lead 3, zinc 3, ash metal 100.

The idea for making this special alloy is to obtain castings of uniform colour and condition.

The fractured surface of a piece of metal is usually a good index to its character. The best fracture is obtained by nicking one side only. The strength of the metal can be judged by the force required to break it, and the angle through which it bends. If ingots are to be judged in this way, they should be broken clean without the chisel being applied, but if this cannot be accomplished, two should be broken, one being cut from the top, and the other from the bottom. This gives a complete view of the fracture, and any irregularity, and the general structure of the metal, whether crystalline or fibrous, can be seen at once.

Mixtures for Plumbers' Brasswork.

The mixtures in use for plumbers' brasswork include some of the standard alloys, such as yellow brass, gun-metal, or German silver, but as the exact proportions for these alloys are not always adhered to in practice, we give here the actual mixtures used in some of the shops:

	Copper.	Zinc.	Lead.	Tin.	
Yellow Brass.					
Standard yellow brass = 2 and 1 alloy	16	8	..	..	
Turning " "	32	16	1	..	
Fine " "	69	29	1	1	
Common " " good casting alloy .	16	9	1	..	
" " " takes high polish .	16	10	..	1	
Coarse " "	16	10	1½	..	
" " " German . .	16	14	..	..	
Strong " " for bolts, nuts, rods . .	60	39	..	1	
Red Metal.					Yellow Brass.
For all kinds of polished fittings .	16	..	1	1	4
And to stand riveting	62	..	4	4	30
" "	66	..	8	4	22
" "	66	..	5	3	26
Cheap red metal	46	..	14	4	36
Cock Metal.					
Stop cocks, bib cocks, etc. . . .	53	..	7	..	40
" " . . .	72	23	5	..	..
" " . . .	16	4	4	..	..
Hose couplings and water-cocks .	50	..	10	5	35
" " .	20	..	2	1	10
					Antimony.
Chemical cocks	16	..	5	..	..
" " for laboratory work .	16	..	2	2	1
" " " " .	16	..	4½	..	½
Hard lead " " " .	2	..	9	..	1
Gun-metal cocks	80	8	8	4	..

German Silver.—*See* Ornamental Brasswork.

BRAZING METAL.

Brazing metal is undoubtedly the most important alloy employed for coppersmiths' work. It is an old standard alloy which is not likely to be supplanted. The essential requirements of good brazing metal are, that it should resemble copper as much as possible in its working qualities, such as malleability and fusibility, and also in colour. In recent years the Admiralty has stipulated the use of copper tubes containing 2 per cent. of aluminium, with the object of working to lighter gauge, and to ensure a more rigid joint with the high pressures now prevalent; but as these tubes are more expensive and difficult to work, being liable to crack both in the fire and under the hammer, they have not been adopted in general practice. The ordinary brazing metal is made from copper and zinc only, but sometimes a small percentage of lead or tin is added to increase the malleability or ductility of the alloy. In making brazing metal, some firms use brass tubes or sheathing instead of adding in zinc, from 1 to 3 lb. of tubes or sheathing to 1 lb. of copper being the common proportions. The mixtures for brazing metal vary according to the size and thickness of the flanges or branches; ordinary mixtures run from 2 to 4 parts zinc to every 16 parts copper; the standard mixture is copper 90, zinc 10. Muntz's best quality is copper 94, zinc 6; and a good mixture for bends or thin castings is

copper 85, zinc 14, tin 1. When more than 20 per cent. of zinc is put into brazing metal, the alloy assumes the characteristics of common brass.

Mixtures for Coppersmiths' Brasswork.

	Copper.	Tin.	Zinc.	Lead.	Iron.	Yellow Brass.	Cock Metal.
Bead metal	90	..	..	8	..	2	..
" "	80	..	..	10	..	10	..
Screw "	84	..	12	4	..	..	..
" "	64	..	..	..	..	32	4
Cock "	62	4	..	11	..	23	..
Pan "	66	4	..	6	..	24	..
Gun " (bolts) . . .	82	8	..	..	..	10	..
" " (for chemicals) .	81	10	..	9	..	..	..
Muntz metal	60	..	40	..	..	..	..
Riveting "	88	1	11	..	..	..	..
Malleable brass	56	..	42	..	2	..	..
" "	57	1	40	..	2	..	..
Naval brass I.	70	1	29	..	..	..	..
" " II.	66	1	33	..	..	..	..
" " III.	62	1	37	..	..	..	..
Rivets (cast)	64	3	24	9	..	..	..

Brazing Solder.*

As the manufacture of brazing solder has drifted largely into the hands of metal refiners and others who make it a specialité, the process of making it is in danger

* Article by the author in *The Mechanical World*, Oct. 26, 1900.

of becoming a "lost art" to the average tradesman engaged at brazier's work. Our modern competitive methods of rushing work through, and increasing the output, are answerable for having thrust into obscurity the preparation of this important commodity.

If coppersmiths and braziers had more intimate knowledge of the composition and working qualities of the particular solder they were using, there would be fewer complaints in the shipbuilding and cycle trades (to go no further) about leaky pipes, faulty joints, or burnt flanges.

There are two methods in general use for making brazing solder. By the first, rods or blocks of the desired alloy are pulverised and graded—coarse, medium, fine—and as we have quite got beyond the age of "mortar and pestle," special plant and machinery are required to accomplish this. The second method is simpler: the molten alloy is poured in a thin stream direct from the crucible into a tank or barrel of water placed in position to receive the dropping metal, about 10 or 12 ft. below. Of course there are other styles of casting solder; in some cases it is passed through a screen or strainer before falling into the water; in others, it falls on to a stream of water which is forced through a nozzle; but as there is no material advantage either way, the direct pouring is commonly employed.

On falling into the water, the metal is split up into little globules, which sink to the bottom. Then the

tank is emptied, and the solder, before it is ready for use, gets a thorough good washing to free it from oxide.

Practical coppersmiths all agree in saying that cast solder has working qualities superior to the machine-made variety, and this is fully borne out by the practice of our large locomotive shops. Personally, we think it is all a matter of usage, and perhaps a want of variety in suitable alloys for different classes of work. It is here that the real advantage of the home-made article comes in. You can make up and modify the alloy to suit the particular work on hand. Nevertheless, we must admit that good cast solder stands more hammering, is more elastic, and runs more freely than the best pulverised on the market.

Before presenting our table of alloys we would emphasise the necessity for using only the best brands of copper, "virgin" spelter, and *clean* water. With these materials, and proper care in the mixing, success is assured. Finally, when melting the copper, whether in the brassfounder's furnace or coppersmith's fire, be careful not to overheat it, and add the spelter with vigorous stirring about ten minutes before pouring. Below we give the pick of the mixtures in vogue for brazing brass, copper and steel:

FOR BRASS.*

1. Copper 50 per cent., zinc 50 per cent.

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* For brazing delicate brasswork a small percentage of silver is sometimes added.

FOR COPPER.

2.	Copper 53 per cent.,	zinc 47 per cent.	= standard English.			
3.	„ 52 „	„ 48 „	= Scotch.			
4.	„ 52 „	„ 47 „	tin 1 = easy melting.			
5.	„ 52 „	„ 47 „	aluminium 1	for high-pressure steam-pipes.		

FOR STEEL.

6. Copper 55 per cent., zinc 44 per cent., tin 1 = for locomotive domes, etc.

7. „ 55 „ „ 44 „ aluminium 1 = for cycle work.

FOR GERMAN SILVER.

8. Copper 35 per cent., zinc 57 per cent., nickel 8 per cent., white.

9. German Silver 60 per cent., zinc 40 per cent., white.

FOR ALUMINIUM BRONZE.

10. Copper 52 per cent., zinc 46 per cent., tin 2 per cent.

The advancement made in the mechanical arts within the last two decades has been so rapid and so widespread that we are likely soon to forget the original significance of the term engineer. This term is now generally applied to metal workers indiscriminately, but a modern definition takes a much wider view, and characterises the engineer as "a man engaged in the work of discovering the forces of nature, and of utilising them for the service of mankind."

The millwright of thirty years ago was the progenitor of the great body of mechanical engineers who are now subdivided into classes, and known as machinists, fitters, finishers, erectors, etc. Up to this point we are

quite clear as to the application of the term, but when we come to consider the many complimentary forms of engineering—so called—we confess our inability to understand the connection. Sanitary engineer, gas engineer, heating and ventilating engineer, cooking and laundry engineer, are our modern euphemisms for the erstwhile "man of smudge," pipe layer, tinker, or handy-man, as the case may be. The mixtures which we give in the following pages are for the guidance of "bona fide" engineers—marine, hydraulic, locomotive, electrical, etc.

Castings which have to stand great hydraulic pressure must be perfectly sound, and as they sometimes show signs of sweating, when being tested, it is a safe rule to have them tested before beginning the different stages of finishing, so that if any faults should appear, they may either be remedied, or the casting discarded, without more loss of labour.

Very often, when the final test is made, the merest trace of moisture shows itself on the surface; yet that is sufficient to condemn the casting for many requirements—as when a given pressure is to be maintained continuously. In such a case, if riveting should fail to cure the evil, or burning be inconvenient, recourse is often had to other expedients, for the finisher is loth to scrap the job after all his labour. Some of the dodges are very simple, and thoroughly effective; for example, the casting is heated gently, plugged, and filled with boiled linseed oil or boiling resin; the heat rarefies the oil, and after the casting is emptied, a film of oil remains inside,

which combines with the oxide in the surface of the metal to form an obstruction over any minute pores.

Mixtures for Marine Engineers' Castings.

Copper.	Tin.	Zinc.	Lead.	Ash Metal.	Yellow Metal.	
..	..	..	..	90	10	"Marine" Brass.
15	..	..	..	85	..	„ „ Special.
46	5	..	3	..	46	Good Bush Brass.
63	6	31	..	..	..	„ „ „
70	3	27	..	..	..	Brass Condensers.
79	3½	17½	..	..	..	„ „ (Doors).
38	..	9	..	53	..	Valve Guards, etc.
30	5	..	..	50	15	Eccentric Straps.
56	7	2	..	35	..	Paddle Pins.
75	4	21	..	..	..	Main Bearing Bushes.
70	14	..	..	..	16	„ „ „
64	8	..	2	..	26	Bilge-pump Plunger.
64	12	..	2	10	12	Piston Rings.
85	12	2	1	..	..	Gun-Metal Pump Chambers.
83	9	..	..	..	8	Gun-Metal (for polishing.
86	10	4	..	..	..	Gun-Metal Shaft Liners.
80	6	8	6	..	..	"Marine" Gun-Metal (tough).
84	3	9	4	..	..	"Marine" Pump Metal.
40	8	2	..	50	..	Head Valves and Foot Valves.
45	5	..	..	50	..	Machinery Brass.

Mixtures for General Engineers' Castings.

Copper.	Tin.	Zinc.	Lead.	Yellow Metal.	Cock Metal.	Ash Metal.	Bell Metal.	
56	9	..	2	10	23	..	..	Bush Metal.
74	7	..	4	15	..	..	..	„ „
42	4	..	6	48	..	..	..	„ „
48	4	..	..	..	..	48	..	„ „
12	10	..	6	72	..	..	..	„ „
16	..	..	..	64	..	..	32	„ „
20	..	..	..	..	..	10	70	Mill Bushes.
10	..	..	..	..	..	20	70	„ „
40	..	..	..	30	..	..	30	Gun-Metal (tough).
30	..	..	..	30	..	..	40	„ (hard).
10	..	..	..	40	..	..	20	„ (tough).
70	8	..	..	22	..	..	..	„ „
32	4	..	2	26	..	36	..	Sluice Valves.
40	6	2	2	..	..	50	..	Pillar Gauges.

	30	5	..	2	14	14	35	..	Junction Pipes.
	78	7	15	..	..	..	..	..	G.M. for covering Rods.
	70	13	..	3	14	..	..	..	,, ,, ,,
	60	6	..	4	30	..	..	..	,, ,, ,,
	72	9	5	14	..	..	..	..	Steam Pressure Cocks.
	84	5	3	8	..	..	..	..	Water ,, ,,
	88½	5¾	5¾	..	..	..	..	..	Bolt Metal.
	84	6¾	2½	6¾	..	..	..	..	Valve ,,
	82	13	5	..	..	..	..	..	Step Bushes.
	86	12	2	..	..	..	..	..	Cog Wheels.
	92	8	..	..	..	..	..	..	,, ,,
	16	2	..	..	2	..	..	..	Hydraulic G.M.
Tested to 4 tons per sq. in.	84	12	..	..	4	..	..	..	,, ,,
	68	10	..	..	6	16	..	..	,, ,,
	84	8	4	4	..	..	..	..	,, ,,
	83	10	4	3	..	..	..	..	,, ,,
Tested to 6 tons per sq. in.	92	6	2	..	..	10	..	..	Special ,,
	Admir	alty G.	M. (87.	8.5) 60	..	20	..	20	,, ,,

Admiralty Alloys.

	Copper.	Tin.	Zinc.	Anti-mony.	Lead.	
Gun Metal	90	10	..	..	..	for Ordnance, and castings subject to shocks.
,, ,, ...	88	10	2	..	..	,, Steam Chests, Pumps, etc.
,, ,, ...	87	8	5	..	..	,, Brackets, and General Engine Fittings.
,, ,, ...	88	12	..	..	..	,, Lighthouse Frames.
,, ,, ...	86	14	..	..	..	,, Hard Bearing Metal.
,, ,, ...	14	1	1	..	..	,, Bolts.
,, ,, ...	10	$1\frac{1}{2}$	..	..	..	,, Hydraulic Pumps, Plungers and Rams.
Phosphor Bronze . .	28	3	..	..	..	Phosphor Tin containing 5 per cent. P to be used.
Bell Metal	78	22	..	..	..	Standard Bell Metal.

Brazing Metal . . .	90	..	10	..	..	Standard Brazing Metal.
Yellow „ . . .	70	..	30	..	..	Fine Yellow, for Tubes, etc.
„ „ . . .	63	..	37	..	..	Common Yellow.
Naval Brass . . .	62	1	37	..	..	for Stanchions, Spindles, Tube Plates, Bolts, etc.
Anti-friction Metal. .	5	85	..	10	..	Admiralty Lining Metal, Plastic.
Special ditto „ . .	8	83	..	9	..	„ for Heavy Load.
„ „ „ . .	7½	85 [illegible]	..	7½	..	German Navy.
„ „ „ . .	7	7½	78½	..	7	French „

The above alloys have all been specified as indicated, for castings by the various Governmental Departments, but this does not exhaust the list of alloys used for Admiralty work. Most of the special alloys of modern times have been specified wherever their introduction was likely to prove advantageous, and this has enhanced the reputation of some of the registered high-tension alloys, as Parsons' and Stone's Bronze, Delta Metal, Bull's Metal, etc. The well-known alloys of Muntz and Babbitt still have a place in the Admiralty repertory, and are subject to severe tests and chemical analysis, in common with all alloys intended for Government. A deviation of more than 1 per cent. from the specified composition or 5 per cent. from the tensile strength required is sufficient to condemn material for this class of work.

Mixtures for Locomotive Engineers' Castings.

Copper.	Tin.	Zinc.	Lead.	Yellow Metal.	Cock Metal.	
80	18	2	..	..	..	Hard Axle Boxes.
80	12	8	..	..	..	„ „ „
84	12	4	..	..	..	Axle Boxes.
86	14	..	..	..	..	Slide Valves.
84	14	2	..	..	..	„ „
90	3½	6½	..	..	..	Stuffing Boxes.
84	16	..	..	..	..	Bearings with heavy friction.
83	15	2	..	..	..	Bearings.
77	9	14	..	..	..	„
72	14	..	..	14	..	Bush Metal.
80	10	5	5	..	..	Red Metal.
50	5	..	3	9	33	„ „
78	3	14	3	..	..	Cock Metal.
60	8	7	7	18	..	„ „
32	2	2	2	..	..	Gauge Cocks.
44	5	..	3	8	40	„ „
82	16	2	..	..	..	Whistles.
57	4	3	..	..	36	„
89	6	5	..	..	..	Piston Rods.
89	11	..	..	..	..	„ Rings.
87	8	4	1	..	..	Steam Chests.
86½	13½	..	..	..	..	Indian Government Railway Bushes.

Special Phosphor Bronze for Slide Valves, etc.

	No. 1.		No. 2.
Ingot Copper	64	..	58
Manganese Copper, 20 per cent. Mn.	15	..	15
Phosphor Tin, 5 per cent. P.	6	..	5
Banca Tin	3	..	2
Cock Metal	12	..	20

Special Silicon Bronze Bearings.

	No. 1.		No. 2.
Copper	76	..	76
Silicon Copper	4	..	4
Tin	8	..	12
Zinc	5	..	..
Lead	8	..	8

Bellfounders' Alloys.

Bellfounding is a declining art, and we believe that bellringing, as a refined accomplishment, reached its highest cultivation in the beginning of last century.

The world is in too big a hurry nowadays, and there are too many distracting noises in the air, for men to be constrained to listen to the softening tones of the "scintillating tin-tin-nabulation of the music of the bells." Bells have had greater vogue as public messengers than ever they had as musical instruments. They were generally known by the suggestive name "long tongue," and some of the methods of ringing them fully warranted the appellation. Beautiful sounds that steal in upon the senses, and linger pleasantly in the memory, are not rightly appreciated in this age of blatancy and brass bands.

This much we gather from the "Police Acts" and "Further Powers" bills which have been promoted by our large cities in order to put down street noises. Bells have been included among the latter, and while

the hawker of the necessary coals or carrots may *bellow* his wares in the street to his heart's content, if he takes to "belling" them he becomes an offender against the civic authority. Similarly, the town-crier's bell has gone out of fashion, although we have retained his preliminary "Notice," and the showman-like "Hi! Hi! Hi!" for attracting attention. The "factory bell" has given place to the "organ" whistle—by the bye, it must have been in irony that "organ" whistles and steam "Sirens" received their names, for the sound of the one has no resemblance to any tone ordinarily produced by the "king of instruments," and the only attraction about the other is its power of drawing one on to find out what all the row is about. Even the menial house bell is degenerating. We cannot think of the electric rattle—it would be a misnomer to call it a bell—as anything but a retrogression in art. "Ting-ting, that's how the bells ring," may be poetry, but it is no longer fact, for the simple bell-pull has been discarded, and now the "press-the-button" fiend is having it all his own way. With the brusqueness characteristic of the times we are instructed to PUSH this modern startler. Some men are said to have made their fortune by PUSH, and business people evidently believe in it, for they have the word boldly inscribed on their door handles as well as on bell-knobs. Electrical science is responsible for not a few of the ills that 20th Century men are heir to. The shock produced by the spasmodic whirr of these electric bells has quite a different effect

from the medicinal shock of Galvani. The telephone would be a wonderful invention, indeed, if it were not such an unmitigated nuisance. Many devices have been tried to lessen the irritating noises emanating from it —isolation, padded rooms, and special attendants—but with little effect. The business man is still liable to suffer from its distracting tr-r-r-ring, and should he unbend to answer the call, as often as not he is foreclosed by a raucous "Hullo! who are you?" or an equally impertinent announcement of some nonentity's identity. With this kind of thing switched on we are "quite up to date, you know"; but it gets on the nerves, and is no more conducive to peaceable reflections than the "disembowelled hurdy-gurdy" to which it has recently been compared.

Perhaps we have gone a little out of the way in noticing the defects of electric bells and apparatus, but we hope we have shown that there is a field for the inventor who can abolish the disabilities of such instruments, and thus conserve the temper of the average city man.

Schiller's "Song of the Bell" was written long before the days of "trusts" and syndicates, but it is still interesting and refreshing reading; it gives us a glimpse of the old-world simplicity of relationship between master and man, and reveals at the same time the early methods of bellfounding. We give an extract from Sir Theodore Martin's translation, published in 'Blackwood's Magazine' for April, 1877.

THE SONG OF THE BELL.

FIRMLY walled up in the earth
The mould is set of well-burnt clay;
To-day the Bell must have its birth—
Then bustle, lads! To work away!
Hotly from the brow
The sweat must trickle now
If the work is to sound the Master's praise.
But the blessing, it comes from above always.

Logs of pine now have them ready,
Dry and seasoned well belike,
That the flames, compact and steady,
May against the cauldron strike.
The copper's fluxed; now in
Quickly throw the tin;
That the tough bell-metal so
Duly may combine and flow.

See! white bubbles now rise thickly!
Good! the mass is fluxing fast;
Stir in the potash thoroughly, quickly,
Then 'twill soon be ripe to cast!
From all scum, too, free
Must the mixture be;
So may its voice, full, clear and round,
From the pure metal then resound.

How brown the tubes grow, have you noted?
  In I dip this wand. If it
Come out with glaze all over coated
  The time for casting will be fit.
    Now, my lads, draw nigh!
    Test the mixture! Try!
If soft with hard is blending well
'Twill then a good result foretell.

Good! Now the casting may begin,
  Clean and sharp is the fracture there;
Yet, or ever we run the metal in,
  Send from the heart a fervent prayer!
    Now strike out the tap!
    God shield from mishap!
Smoking the fiery tide shoots down
The handle's arch, all dusky brown!

Now 'tis lodged within the ground,
  The mould is finely filled! Ah, will
The bell come forth complete and sound,
  To recompense our toil and skill?
    Has the cast gone right?
    Has the mould held tight?
Ah, while we still are hopeful, thus
Mischance perhaps has striken us!

Till the bell cools down, we now
  From our anxious toil may rest.
Free as happy bird on bough
  Each may do as likes him best.
    At set of sun,
    His duty done,
The 'prentice hears the vesper toll,
But rest there is none for the master's soul.

Now, break me down the walls there! They
  In our work have done their part—
That our successful casting may
  Rejoice both eye and heart.
    Smite, stroke on stroke,
    Till the cover's broke!
Ere the bell can rise from the pit below
The mould must into pieces go.

God unto me great joy has given.
  Behold! Like any golden star,
From its shell the metal kernel riven
  Shows clean and smooth, not a flaw to mar.
    From crown to rim it gleams
    Bright as the bright sun's beams;
The scutcheons, clear and sharp, also,
The skill of the hand that limned them show.

Now tackle to the ropes and prise
The bell up from the pit, that so
She to the realm of sound may rise,
  High up aloft where the breezes blow!
    Pull, pull, lads! See,
    She waves, swings, free!
Joy to our town may this portend,
Peace the first message be she forth shall send.

The desire for huge bells was developed in the middle ages in order to proclaim the sway of the church. Many bells bearing testimony to the skill of the metal workers of this period remain with us, and some of the most prominent incidents in history are associated with them. We need only mention

"Curfew," the Bishop's bell—or the ceremony of "bell, book and candle"—the warning bells placed on rocks or dangerous promontories, like the famous Bell Rock, to guide the mariner's course; while among the customs that have survived we may include the mariner's "8 bells," the "Sabbath bells," "proclamation bells," the festive "carillons," marriage bells, funeral knells, and the pompous dinner bell.

The largest bell in Gt. Britain is "Great Paul" in St. Paul's Cathedral, cast in 1881, and weighing about 18 tons; but the most famous bell we have is probably "Big Ben" at Westminster, named after Sir Benjamin Hall, First Commissioner of Works in 1856, when it was cast. There have been two musical giants of this name, and they have both been unfortunate, as within a year after being hung they were both found to be cracked. The first Big Ben was cast by Messrs. Warner, Houghton-le-Spring, Durham, from a bronze composed of 22 parts of copper and 7 parts of tin. Its diameter was 9 ft. 5½ in., while its height was 7 ft. 10½ in.; it weighed 15 tons 8 cwt., and the clapper 12 cwt.

About a year after it was hung it was discovered to be cracked, so it was broken up, and Messrs. Mears, of Whitechapel, cast another from the same metal, but about 2 tons lighter; the hammer also was much lighter—about 6 cwt. In a short time this bell was also found to be cracked, but the fault was remedied by filing the crack open, and in this condition Big Ben

continues to mark time with no uncertain sound—its note is E natural.

A very interesting bell is the Kaiserglocke, at Cologne Cathedral, weighing over 26 tons, and cast in 1874 from twenty-two French guns captured in the Franco-Prussian war, valued at £3740. The Kaiserglocke is probably the largest swinging bell in the world, for those at Pekin and Moscow, though larger, are fixed bells. The diameter on the lower rim is 13 feet, and the height is 17 feet.

"Ivan the Great," the monster bell at Moscow, is undoubtedly the largest bell in the world, being nearly 68 feet in circumference, and over 21 feet in height; it is now used as a kind of temple. In its stoutest part it is 23 inches thick, and its weight has been computed to be 198 tons. It has never been hung, and was probably cast on the spot where it now stands—at the foot of the Kremlim. A piece of the bell is broken off, and the gap is used as an entrance. According to tradition the fracture was made by water having been thrown upon it when heated by the building erected over it being on fire.

There is another great bell at Moscow, in the Church of the Redeemer, which weighs about 30 tons. It was dedicated in memory of the emancipation of the Bulgarians. When the bell was delivered at the church by the contractor who cast it, he declared its weight to be 1802 puds or 36,040 kilograms (35 tons 7 cwt. 104 lb.). Some members of the

committee who had charge of the business were not satisfied with the statement of the bellfounder, and took steps for having the weight of the bell ascertained independently. It was found that the actual weight was 6960 kilograms (6 tons 16 cwt. 80 lb.) less than had been stated, which made a difference in the price of 3201 roubles (about £480).

The famous "Liberty Bell" was made by order of the Province of Pennsylvania for the State House, Philadelphia, in 1752.

The commission for the bell was awarded to Robert Charles, London, the specification being that the bell should weigh about 2000 lbs., and cost £100 sterling. The bell arrived in apparent good order, but it was cracked while being tested. Two tradesmen belonging to the State undertook to re-cast the bell, which they successfully did by adding a quantity of copper to the composition of the original bell. This bell was placed in position in June 1753, and, true to its motto, proclaimed "Liberty throughout the land and to all the inhabitants thereof." For fifty years it continued to be rung on every festival and anniversary, until it eventually cracked. An attempt was made to cause it to continue serviceable, by widening the crack and chipping the edges, but it proved ineffectual. Its year of jubilee had come!

These are only a few of the incidents related of some of the prominent bells with a history, but there is such a vast amount of heart-stirring romance and

national sentiment connected with bells and the uses that have been made of them, as would require a goodly volume. Contrary to the popular idea, the tone of a bell depends not so much on the metal, as on its form and the proportions of its various dimensions. This is especially true of chimes and peals, and it has been well said that "the successful manufacture of chimes can only be done by those whose knowledge of the business is as accurate as instinct, and this is possessed only by those who have followed the business for a lifetime."

The Chinese tam-tams or gongs are distinguished by a strong far-reaching sound, which is obtained by a process of mechanical treatment, tempering and hammering. Bell-metal should be hard, compact, and of fine grain.

The following table shows the composition of some bell-metals:

ANALYSES OF BELLS.

	Copper.	Tin.	Zinc.	Lead.	Silver.	Iron.
Alarum Bell at Rouen	76·1	22·3	1·6	..	1·6	..
Bell at Ziegenhain .	71·48	33·59	..	4·04	..	0·12
„ „ Darmstadt .	73·94	21·67	..	1·19	0·17	..
„ „ Paris . . .	72·0	26·56	..	..	1·44	..
Tam-tam	78·51	10·27	..	0·52	0·18	..
Bells of Japanese origin, "Karakane"	10	4	1·5	..	0·5	..
	10	2·5	0·5	1·33	..	..
	10	3	1	2	½	..

BELLFOUNDERS' MIXTURES.

	Copper	Tin.	Zinc.	Yellow Metal.	Iron.	German Silver.
1. Standard I. (best tone) .	78	22	..	..	..	..
2. „ II.	80	20	..	..	..	..
3. Large Bells	76	24	..	..	..	..
4. House „	76	16	..	8	..	..
5. „ „	78	20	..	2	..	..
6. Clock „ (Swiss). .	75	25	..	..	..	..
7. „ „ (Special) .	80	20	..	4	..	4
8. Sleigh „	84	16	..	..	..	..
9. Silver „	40	60	..	..		..
10. „ „	50	..	25	Nickel 25		..
11. Ship „	82	12	6	..	..	..
12. Railway Signal Bells .	60	..	36	..	4.	..
13. Gongs	82	18	..	..	..	..
14. White Table Bells . .	..	7	Antimony 1		..	..
15. „ „ „ . .	2½	97	Bismuth ½		..	..
16. „ „ „ (Special)	..	19	Nickel 80		Platinum 1	

CHAPTER V.

THE MODERN ALLOYS.

The modern alloys are the growth of practical experience and scientific research. We are continually making advances in the mechanical arts, and, of necessity, the materials used must be adapted to meet the requirements of the age. Engineers multiply powers, and manipulate pressures, in a way that would have appalled the mechanic of 40 years ago. Machinery is more ponderous, more complicated, and more severely tested now than ever it was, and machine parts require to have greater accuracy and strength. It has taken many years of careful application and study to bring the modern alloys to their present high standard. New alloys are patentable in this country, but unless there should be some "difficulty," "secret," or "invention," in the process of making the alloys, the patents are generally valueless, and if the constituents are once known, they soon become the common property of all.

The brass trade is also badly afflicted with another

bugbear in the shape of registered brands with symbolical names in imitation of original and scientific alloys, such as phosphor bronze, aluminium bronze, manganese bronze, Muntz metal, or Dick's Delta metal.

Strictly speaking, none of these metals are bronzes, i.e. alloys of copper and tin—excepting perhaps phosphor bronze, from which most of the phosphorus has been eliminated by the process of mixing—but as they possess all the virtues of true bronze, and in some cases something over, they can be quite legitimately called "high tension alloys," and we can afford to let the name pass. It is when we take up some of the highly-puffed fancy-priced nostrums having similar names that we feel inclined to quarrel. Take aluminium bronze as an example: most of the aluminium bronzes which are made at the present time are simply brass with a small per cent. of aluminium added in. Now the original formula for aluminium bronze, as everybody knows, was copper 90, aluminium 10—quite a different alloy. Delta metal is another alloy which has been badly imitated by not being made according to the inventor's method. Brass containing iron was made long before Mr. Dick brought to light the proper method and proportions for combining these metals, but there is no comparison possible between the old and new copper-zinc-iron alloys. The principle applications of Delta metal are for marine and general engineering, shipbuilding, mining, hydraulic and

chemical work, for electrical and sanitary purposes, etc. The alloys produced by the Delta Metal Company, Ltd., vary in composition according to the requirements of the different purposes for which each of these alloys is more particularly suitable. While some of them are based upon the introduction and chemical combination of definite quantities of iron in copper-zinc alloys (Alexander Dick's original patents), others are improvements on various bronzes, Babbitt's metal, etc. Some Delta alloys possess in a very high degree the properties of malleability, strength, and resistance to corrosion; others are superior bearing metals; others again have particular qualifications for electrical purposes; but each alloy has special points of excellence which render it eminently suitable for certain classes of work.

Delta metal is non-magnetic. On this account it is much employed for parts of dynamos, and for tools used in connection with electrical work, such as spanners, etc. Wrought Delta metal is stronger than steel; bolts and nuts are extensively used for all engineering purposes where durability and resistance to corrosion, combined with strength, are important. Delta metal is often used for bells and gongs. These are very sonorous, and such bells may be cast lighter than usual on account of the greater strength of Delta metal.

Delta metal was patented in 1882 by Alexander Dick, and it has enjoyed a well-merited run of popularity since; its composition is somewhat similar to

the well-known Sterro metal, but in making Delta metal, the iron is previously alloyed with zinc in known and definite proportions. When ordinary wrought iron is introduced into melted zinc, the latter readily dissolves or absorbs the former, and will take it up to the extent of about 5 per cent. or more. It is claimed that by this process the iron is chemically combined in the bronze, and among other advantages claimed for Delta metal are increased strength and toughness; it produces sound castings of close grain, and can be forged hot or cold. When cast in sand its tensile strength is about 45,000 lbs. per square inch, with about 10 per cent. elongation; rolled, it may stand 75,000 lbs. tensile strain, with 9 to 17 per cent. elongation, on bars 1·128 inch diameter and 1 inch area. Hirons states that the inventor of Delta metal uses a small amount of phosphor copper to avoid oxidation when the alloy is remelted, and in some cases he uses tin and manganese to impart special properties.

The following analyses, derived from Delta metals, produced by the "Deutche Delta-Metall Gesellschaft," have been widely circulated in American publications:

	Copper.	Lead.	Iron.	Manganese.	Zinc.	Nickel.	Phosphor.
Cast . . .	55·94	0·72	0·87	0·81	41·61	trace	0·013
Wrought . .	55·80	1·82	1·28	0·96	40·07	trace	0·011
Rolled . .	55·82	0·76	0·86	1·38	41·41	0·06	trace
Hot Punched .	54·22	1·10	0·99	1·09	42·25	0·16	0·02

Another analysis by Professor Roberts-Austen shows:

	Copper.	Lead.	Iron.	Manganese.	Zinc.	Nickel.	Phosphor.
	55·10	0·10	1·08	..	43·47	..	0·10

Instead of alloying the zinc and iron for Delta metal, an alternative method is sometimes used by brassfounders. Ferro-manganese or phosphor copper and manganese copper are used as substitutes, the average composition being: copper 50, zinc 43, manganese copper 5, phosphor copper 1, lead 1. An excellent casting quality, having superior mechanical properties, is composed of: copper 55, manganese copper 8, zinc 36, lead 1. Mr. Brannt describes the best method of preparing a zinc-iron alloy as follows:—Heat 1 to 2 lbs. of zinc in a clay crucible to the melting point, then throw 3 to 3·5 oz. of anhydrous sodium ferrous chloride upon the surface of the melted zinc, and immediately cover the crucible. A very vigorous reaction takes place during the formation of the alloy mixed with zinc chloride ($Zn + FeCl_2 + Fe$). The excess the of zinc alloys with the reduced iron and forms the exceedingly brittle zinc-iron which can be readily pulverised. *Zinc-iron* as an alloy of a very volatile with a non-volatile metal, presents an interesting problem in the science of metallic alloys.

Manganese Bronze.

We believe in calling things by their right names, and so far as we can see there is no plausible reason why manufacturers should call a brass by any other name. Manganese brass and aluminium brass would be more correct descriptions of alloys which are admittedly superior to the best bronzes for many purposes. The only reason that manufacturers can give for continuing the appellation " bronze " to these metals is that consumers have been used to paying a much higher price for bronze than for brass, and if they get a metal with superior qualities, they should be willing to pay a good price for it.

It is a comparatively easy matter nowadays for the brassfounder to make special alloys containing known percentages of iron, manganese, nickel, aluminium, and the metalloids phosphorus and silicon, as all these are now manufactured in combination with his ordinary metals—copper, tin, zinc and lead. These special alloys are very convenient for converting the ordinary bronze alloys into high tension or non-corrosive bronzes, or for improving the common brass alloys.

Phosphor Copper	usually contains from	10 to 15 %	Phosphorus
„ Tin	„ „ „	5 %	„
Ferro-Zinc	„ „ „	5 %	Iron
Silicon Copper	„ „ „	10 to 30 %	Silicon
Manganese Copper	is made containing up to	30 %	Manganese
Ferro-Manganese	„ „ „ „	50 %	„
„ Aluminium	„ „ „ „	50 %	Aluminium

Formerly, when the brassfounder attempted the manufacture of alloys containing these metals, with "free" phosphorus — in sticks, manganese-dioxide Mn_2O—black manganese powder, ground bottle-glass or iron filings, the results were uncertain and often unsatisfactory. With the advent of the electric furnace, and the recent science of electro-metallurgy, great advances are being made in alloying the rare and refractory metals, but up to the present time they have been chiefly employed for the production of special kinds of iron and steel. Various grades of ferro-chromium, ferro-silicon, ferro-tungsten, and ferro-molybdenum, for steel makers' use, were exhibited in the Paris Exhibition, 1900. Structural engineers had their attention directed to foundry irons of a specially desulphurised class, which are coming into favour for some kinds of work, and electrical engineers were interested in a peculiar application of aluminium in place of copper for conveying a heavy electric current. To anyone interested in alloys these combinations are of great interest, but as they have not yet been applied in brassfoundry practice, we content ourselves with simply mentioning them. Next to nickel-steel, manganese bronze is probably the most favoured of the modern alloys for machine parts requiring great strength and resistance to corrosion.

The alloy of copper with manganese so-called manganese-copper ordinarily contains:

Manganese	20 %
Copper	76 % to 78 %
Iron	2 % „ 4 %

and this is used by brassfounders to make manganese bronzes. It is found that from $\frac{3}{4}$ per cent. to 2 per cent. manganese (or from 5 per cent. to 10 per cent. of manganese-copper containing 20 per cent. of manganese) in a bronze is sufficient to make ordinary manganese bronze.

To make a good manganese bronze, using 20 per cent. manganese-copper, the following mixture is frequently used:

Copper	51 parts
Manganese copper	8 „
Zinc	40 „
Aluminium	1 „

This, in cast ingots, gives 36 to 38 tons per square inch tensile strength, and 20 to 22 per cent. elongation.

If the engineer requires greater hardness and increased tensile strength, but less elongation, a larger percentage of zinc is used; but if a greater elongation is required, a smaller percentage of zinc must be employed.

There are two important classes of manganese bronze; they are known by the trade as yellow manganese and red manganese. The alloys of the former are akin to Muntz's metal, and are particularly suitable for casting propellers, parts of guns and gun-carriages, while the red alloys are adapted for bearings, worm-wheels, and similar parts exposed to wear.

The United Alkali Company, Ltd., supply the various qualities of manganese bronze according to the

purposes for which they are required. They also make a "standard metal" of copper, manganese-copper and aluminium, so that the foundor has only to take, say, 60 parts "standard metal," and add to it 40 parts of zinc. They give the following tables, showing the results obtained by using "standard metals" and zinc in varying proportions:

	Standard Metal.	Zinc.	Tensile Strength.	Elongation.
	parts	parts	tons per sq. in.	per cent. in 2 in.
1	66	34	34·00	30·0
2	64	36	37·75	18·0
3	63	37	39·75	18·0
4	62	38	41·00	22·5
5	60	40	41·50	24·0
6	58	42	38·50	17·0
7	57	43	38·00	15·0
8	56	44	34·50	10·0
9	55	45	33·00	9·0
10	53	47	33·00	9·0

In a pamphlet relating to their registered "Stella" alloys, they enlarge upon the great value of manganese bronze for ships' propellers and machinery bearings.

They say it works much cooler, and, consequently, needs less lubricating than phosphor bronze or gunmetal, and considering the high price of tin, this manganese alloy, which is superior in quality to the tin alloys in many ways, and considerably less in price,

should prove most acceptable to engineers. Many brassfounders have not had experience in casting alloys containing a large percentage of zinc. They are accustomed to melt and cast ordinary bronzes containing tin and gun-metal. When, therefore, they have attempted to cast this class of metal, they have failed, and the metal has been condemned through the inexperience of the caster.

The tendency of zinc to volatilise, and of both zinc and aluminium to oxidise, indicates the main precautions that must be taken to secure sound castings. The metals must not be roasted, i.e. exposed at a dark heat to an oxidising influence; they must not be overheated, or there will be an excessive loss of zinc (not more than 2 to 3 per cent. of zinc should be lost in melting the charges in pots); but it is most important that the vents in the moulds should be ample, and that all air should be expelled before the inflowing metal. Hence the expediency of casting from the bottom, and preventing any air rising through the body of the casting. This class of metals has a tendency to sink or draw; therefore, there must be ample "gits," which must be well fed or pumped. Such serious blunders have so frequently been made in the foundries that some of the makers of manganese bronze refuse to supply this metal in ingots. If castings are required, they will supply castings; but experience, intelligence, and care should certainly overcome the difficulties which this class of metal presents.

An alloy of manganese 5 parts and copper 95 parts has been found to possess great strength, and a high resistance to change in structure, when subjected to high temperatures. The addition of manganese seems also to add considerable hardness to this class of alloy. The following analyses were derived from two manganese bronze propellers supplied recently —one by a London firm, and the other by a firm in Glasgow :—

I.

Copper	56·78
Tin	0·48
Zinc	41·60
Iron	1·05
	99·91

II.

Copper	66·95
Zinc	29·60
Aluminium	1·93
Iron	1·00
Lead	0·50
	99·98

An analysis of manganese bronze, however, gives no criterion of the amount of manganese originally used in the preparation of the alloy, as, if ferro-manganese is employed, a considerable quantity of the iron remains in the finished alloy, while the residual manganese may be very minute. We give opposite some of the ordinary mixtures for manganese bronze:

MANGANESE BRONZE ALLOYS.

Copper.	Zinc.	Tin.	Lead.	Yellow Metal.	Aluminium.	Nickel.	Manganese Copper.	Manganese dioxide.	Cold Blast Iron.	Ferro-Manganese.	Ferro-Aluminium.	
64	..	8	..	8	..	..	..	7	..	..	..	Old Style
80	..	10	..	10	..	..	..	5	..	..	..	„ „
60	15	..	..	..	..	..	..	25	..	..	..	„ „
80	..	10	..	..	..	..	10	..	..	..	..	Genuine bronze for bearings, etc.
74	5	8	3	..	..	..	10	..	..	..	..	Red „ „ machine parts.
56	40	1	..	..	..	..	..	..	3	..	..	Yellow „
55	42	..	..	..	2	..	..	..	1	..	..	Richards' „
50	43	1	..	..	..	..	6	..	..	..	..	Bronze for propellers
55	40	1	..	..	..	1	..	..	3	..	..	Preston's bronze
82	..	..	..	..	..	10	..	..	8	..	..	„ „
64	31	1	..	..	2	..	..	..	2	..	..	"Durano" „
62	32	..	..	..	..	..	..	..	..	6	..	
58	38	..	..	..	..	..	..	..	..	3	1	French „
56	40	..	..	..	..	..	..	..	..	..	4	„ „
80	5	6	..	..	..	..	9	..	..	..	..	Special „ tough
81	..	17	..	..	..	..	2	..	..	..	..	„ „ hard
56	42	..	..	..	..	..	2	..	..	..	..	Malleable „

Note.—The foregoing mixtures are based on cupro-manganese containing 20 per cent. Mn, ferro-manganese containing 50 per cent. Mn, ferro-aluminium containing 50 per cent. Fe. The amount of manganese in cold-blast iron is always a variable quantity.

Phosphor Bronze.

Mixtures of certain metals with phosphorus were well described as a scientific discovery about fifty years ago by Pelletier, Henry Rose, and Berzelius, and the many uses to which it has been put in refining and alloying metals are well known in the engineering world.

Briefly, the theory of its application in bronzes is, that it possesses a deoxidising power, reducing the cuprous oxide formed by the absorption of oxygen in copper and copper alloys during fusion. If only so much phosphorus is used as is necessary for the work of reduction, it is consumed again by the work done, and no superfluous phosphorus remains in the metal; and while to the analyst there may be no evidence, or only a trace, of phosphorus, the metal will show physical signs of the addition in increased strength, density, malleability, and homogeneity. In 1871, Montefiori, Levi, and Kunzel were instrumental in perfecting a method of producing phosphor bronze by preparing copper phosphide and phosphide of tin, and dissolving small portions of these in the usual bronze

alloys while in a molten condition. The enhanced qualities of the bronzes so made were soon recognised, and since then phosphor bronze has been a popular metal in the engineering industries, displacing gun-metal and steel for many purposes. When properly made, the phosphor bronze alloys are exceedingly thin when melted, and the fluid metal is not covered with a skin of oxide, but its surface is bright and mirror-like, showing the distinctive difference between this and ordinary bronze. Another characteristic of genuine phosphor bronze is observed as the metal cools; it sets suddenly, and passes directly from the fluid into the solid state without first becoming pasty. It is commonly allowed that phosphor bronze may be repeatedly remelted without any loss of tin taking place, although the amount of phosphorus decreases slightly. Mr. Brannt directs attention to another peculiarity of this preparation. "Besides reducing any oxides dissolved in the alloy, the phosphorus exerts another material influence upon its properties. The ordinary bronzes consist of mixtures in which the copper actually forms the only crystallised constituent, the tin crystallising with great difficulty, and the alloy, in consequence of this dissimilar condition of the two metals, is not as solid as it would be if both constituents were crystallised. The presence of phosphorus is useful in giving the tin a crystalline character, which enables it to alloy itself more completely and strongly with the copper, the result being a more homogeneous mixture."

Advantage is sometimes taken of the deoxydising power of phosphorus, by the brassfounder or metal refiner, to improve inferior qualities of brass, and to get them to stand the physical tests of higher class alloys. Dr. Kunzel deprecates strongly the use of zinc in phosphor alloys, and phosphor bronzes bearing his name are always warranted free from zinc. He patented, however, a remarkable alloy, containing a good percentage of lead, which has been eminently successful for bearings, and the wearing parts of machinery.

The alloy referred to was composed of copper from 66½ to 91½ per cent., lead 4 to 15 per cent., tin 4 to 15 per cent., and phosphorus ½ to 3½ per cent. The mean of these figures gives an alloy bearing a close resemblance to the registered "Ajax Bronze," so largely used for rolling mill, sugar mill, and locomotive bearings. A similar alloy is used by a large railway company in America, showing copper 79·7, tin 10, lead 10, and phosphorus 0·3.

The Chicago, Burlington and Quincy Railway Co.'s phosphor bronze used to be made by adding 6 per cent. of pure phosphorus to ordinary gun-metal = 90·10. The phosphorus was prepared by being steeped in a solution of copper sulphate until a coating of copper was deposited on the sticks. After being dried it was then introduced into the molten bronze by means of a cup-shaped instrument.

PHOSPHOR BRONZE ALLOYS.

	Copper.	Banca Tin.	Lead.	Yellow Metal.	Phos. Copper.	Phos. Tin.
Standard	90	..	..	..	..	10
Feed screws . . .	16	1	..	..	..	1
Pinions	16	1	..	2	..	1
Bearings	80	8	8	..	4	..
Liners	28	3	..	4	1	..
Propellers. . . .	84	8	..	5	3	..
Cocks and fittings .	100	6	12½	..	..	6½
Bushes	75	11	7	..	7	..

ALUMINIUM BRONZE.

In some respects aluminium has been an over-exploited metal. When the production of aluminium was so far cheapened that it could enter into competition with most of the common metals, it was recommended extensively, and used indiscriminately, without due consideration being given to its peculiarities. The results were most discouraging to manufacturers, and retarded for a time the adoption of the metal for many purposes for which we have now to acknowledge it is admirably suited. New uses are constantly being found for aluminium, especially in the electrical and structural industries; and as it is a metal which may very easily be denuded of many of its best properties through unskilful handling, we gather a few useful hints for the guidance of those interested. The treatment which it is customary to apply to other metals is not always appli-

cable to aluminium, or alloys containing aluminium. It is admittedly difficult to work with—especially in soldering and casting. The specific gravity of aluminium is so small, in comparison with most other metals, that perfect union in an alloy is not easily accomplished.

Then the susceptibility of some aluminium bronzes to corrosion and galvanic action was the cause of great disappointment to engineers. In spite of the fact that complex alloys of aluminium have not yet been successful, and notwithstanding the drawbacks which the improper uses of the metal have revealed, aluminium is still a wonderful metal, and continues to advance in the scale of usefulness. It has quite ceased to be a curiosity, and there is a steadily increasing demand for it in innumerable branches of trade. Shipbuilding, electrical engineering, and metallurgy absorb a great quantity of aluminium for the heavy alloys, while vehicular fittings, army equipment, cooking utensils and general articles of ornament and convenience take up the bulk of the pure metal manufactured.

The useful alloys of aluminium may be divided into two classes—light alloys, containing from 1 to 10 per cent. of other metals, and the heavy alloys, consisting of other metals combined with from 1 to 10 per cent. aluminium.

Aluminium bronze, strictly speaking, is not a bronze, as it contains only copper and aluminium. It is a valuable and generally useful alloy, however, containing from 3 per cent. to 10 per cent. aluminium. The mechanical properties of aluminium bronzes are

greatly improved by a small addition of iron—about ·25 per cent. M. Partin, a French engineer, has brought out a new alloy of aluminium and tungsten, called "Partinium," which is in great favour on the Continent. Another series of French aluminium alloys containing tin, copper, zinc, aluminium, and having specific gravity from 2·8 to 7·1, are largely used for light machines and structural work. Aluminium is now being used extensively for the reduction of metals which could not be produced previously in a pure state commercially; also in the manufacture of steel and iron castings; and lately for welding steel and iron. The welding of steel rails for tramways, iron tubes, and steel castings has already been accomplished by the oxidisation of aluminium, and it is impossible to foretell what in the future may yet be accomplished in the way of industrial art. Professor Arnold states that the effect of even small quantities of aluminium in producing steel free from blow-holes is perhaps the most remarkable phenomenon in the metallurgy of steel.

By the generation of intense heat, through the combustion of aluminium in the presence of a metallic superoxide, a temperature of 3000° Centigrade can be obtained.

The application of this process for welding is due to the researches of Dr. Hans Goldshmidt, Essen, and patents have been secured for "Thermit"—the registered name of the heating agent—in all industrial countries by Messrs. The Chemische Thermo Industrie, Ltd., Essen-Rhur, Germany.

Dr. Mach has introduced a new alloy which, it is claimed, will probably supersede iron and steel. It is called magnalium, and consists of 100 parts of aluminium, and from 10 to 30 parts of magnesium. It is one-third the weight of brass, and can be made as workable or as hard as desired. It is pure white, takes a higher polish than silver—hitherto the most polishable metal—and has all the merits and none of the defects of pure aluminium. At present it is being used in Berlin for scientific instruments, and the mounting of opera-glasses.

Hitherto soldering has presented many difficulties, but Heraeus, of Hanau, in Germany, has succeeded in jointing the metal by a new method called autogenous soldering. He takes advantage of the fact that at a certain temperature, far below its melting point, aluminium becomes plastic, and can be kneaded.

The two edges to be united are raised to, and maintained at, this temperature, and are kneaded together until an homogeneous mass of metal has been produced at the point of contact.

Aluminium solders are plentiful, and many patents have been obtained for alloys by means of which "soldering presents no difficulty." The following alloys are all suitable for soldering aluminium, or alloys of aluminium:

No. I.—Zinc, 57 %; cadmuim, 43 %.
„ II.—Zinc, 30 %; tin, 65 %; bismuth, 5 %.
„ III.—Aluminium, 3 %; phosphor tin, 3 %; lead, 27 %; blcck tin, 67 %.

Aluminium Alloys (Light).

Alumn.	Copper.	Zinc.	Nickel.	Tung-sten.	Mag-nesium.	Iron.	Tin.	
98	1	..	1	..	..	..	..	
98	..	..	1	1	..	..	..	
96	4	..	..	..	..	..	..	No. 4 aluminium.
96	..	..	..	4	..	..	..	French „
94	6	..	..	..	..	..	..	No. 6 „
94	4	..	2	..	..	..	..	Malleable „
88	..	12	..	..	..	..	..	
80	5	15	..	..	..	..	..	Very rigid alloy.
70	3	27	..	..	..	..	..	Rigid alloy.
4	6	90	..	..	..	..	..	Art castings.
90	..	..	..	..	10	..	..	" Magnalium."
100	..	..	..	..	..	..	10	

Aluminium Bronze Alloys (Heavy).

5	95	..	..	..	..	..	..	Genuine alumn. bronze.
8	92	..	..	..	..	..	..	„ steel bronze.
10	90	..	..	..	..	..	..	„ acid bronze.
3	97	..	..	..	..	..	..	„ gold bronze.
8	84	Silicon Copper			8	..	..	Special machine bronze.
8	77	„		„	15	..	..	No. 2 „ „
14	76	Manganese „			10	..	..	American „ „

Aluminium Brass Alloys.

2	58	40	..	..	..	..	..	Marine bronze.
3	57	40	..	..	..	..	..	„ „
2	55	42	..	..	..	1	..	Propeller blades.
2	67	30	..	..	..	1	..	
2	69	29	..	..	..	..	..	
2	64	32	..	..	..	1	1	" Durano " metal.
2	60	30	..	..	..	..	..	Cowles'.

Aluminium Bronze with Silicon.

			Silicon.					
7½	90½	..	2	..	..	..	..	British Aluminium Co.'s.
2	63	33	2	..	..	..	..	High tension bronze.

The following shows the results of tests of aluminium brass made by Cowles Bros., the alloys being all made by adding zinc to aluminium bronze:

Aluminium Brass.*

Composition.			Tensile Strength per square inch. Castings.	Elongation.
Aluminium.	Copper.	Zinc.		
			lbs.	per cent.
5·8	67·4	26·8	95,712	1
3·3	63·3	33·3	85,867	7·6
3	67	30	67,341	12·5
1·5	71	27·5	41,952	27
1·5	77·5	21	32,356	41·7
1·25	70	28	35,059	25
2·5	70	27·5	40,982	28
1	57	42	68,218	2
1·15	55·8	48	69,520	4

Anti-Friction Metals.

What is known as "Babbitting" is the process, well known to engineers, of lining journals, bearings, or surfaces subject to friction with some soft anti-attrition material, with the double object of doing away with the more costly solid bearings in gun-metal or red brass, and also of reducing to a minimum the friction of machinery parts moving upon one another.

Mr. Izaac Babbitt made a special study of bearings,

* The *Engineer's Year-Book*, 1897.

and although his original patent was for a particular form of bearing, and not for an anti-friction metal of special composition, as is generally supposed, he followed up the art of making anti-friction alloys with such success that his name has been employed to describe the metal as well as the process for filling bearings.

His first anti-friction metal was composed of tin 90 parts, copper 10 parts, but at a later period he improved on this, and produced an alloy which is still the standard anti-friction metal. This alloy is made by melting separately 4 parts of copper, 8 parts of antimony, 24 parts of tin, the antimony being added to the tin after fusion. The copper is introduced after the melting pot containing the tin and antimony has been removed from the fire, and the whole charge is kept from oxidation by covering the surface with a layer of powdered charcoal. The "lining metal" consists of this "hardening" fused with twice its weight of tin, thus making the final composition 3·7 parts of copper, 7·4 parts antimony, and 88·9 parts tin.

This is the method and proportions for making "genuine Babbitt metal," but there are countless rival preparations called by that name. In recent years, no group of alloys has been so elaborately experimented with, or so universally adopted in general engineering practice, as the so-called "white anti-friction metals."

Their name is legion; and if we can believe half of what is put out about them, it may be said that Babbitt has been fairly out-babbitted. According to the ad-

vertising columns of the engineering journals, "the finest anti-friction metal in the world" has been discovered on several occasions, one firm claiming to have "headed the procession in '78 and ever since."

The qualities sought after in this class of metal are: (1) low co-efficient of friction; (2) low melting point or fusibility; (3) small contraction; (4) plasticity; (5) high pressure capacity; and (6) indifference to the action of sea water and acids. We are *not* interested in any particular brand of anti-friction metal, so we make no invidious comparisons, but as we have gone to the trouble of having several analyses made of high-class alloys which are in repute and often specified by engineers, we submit the results for the good of those who are in any way interested in the anti-friction metal subject. Many engineers and brassfounders prefer to make up their own metal for this class of work; this preference is, in all likelihood, due to the fact that a great number of trashy mixtures are on sale at fancy prices, and for a long time these have been foisted upon them by manufacturers.

ANALYSES OF HIGH CLASS ANTI-FRICTION METALS.

	Copper.	Tin.	Antimony.	Zinc.	Lead.
I.	3·45	78·56	0·16	..	14·36
II.	3·8	78·56	11·8	..	6·0
III.	3·61	74·22	6·55	1·80	13·50
IV.	1·80	64·70	..	33·35	1·00

When alloys of lead, zinc and antimony are melted in contact with the air, the antimony is oxidised much sooner than the lead, and, on account of the volatility of the antimony and zinc, the alloy becomes more viscid and difficult to fuse the oftener it is remelted. To avoid waste, first make what is called a lead "bath," by melting half of the lead to be used, then add the zinc and antimony in small pieces, and when melted, add the balance of lead.

The German Admiralty specifications for Babbitt metal demand that 6 parts of tin be combined with 1 part of copper, while other 6 parts of tin are alloyed with 1 part of antimony in a separate crucible. When both of these alloys are thoroughly liquefied, they are brought together by pouring the one into the other, and mixing well. The combined alloy is then poured into ingots, and remelted before being used for filling bushes or interspacing slide valves. Many other methods of making Babbitt metals could be described, but those already given are typical of the best methods in present use for obtaining reliable alloys of constant homogeneity and composition.

Special Anti-Friction Metals.

It has been observed by Kirchweger, that a small content of phosphorus in anti-friction metals prevents blistering, promotes fluidity, increases the hardness, re duces friction, and improves the fusibility of the alloy

Many white anti-friction metals containing phosphorus are in use. The following are considered to be among the best in this class:

No. I.—Tin, 82: antimony, 9; standard phosphor bronze, 9.
Suitable for solid bearings, or shafts having heavy wear.

„ II.—Tin, 75; antimony, 15; standard phosphor bronze, 10.
For locomotive or general engine bearings with high speed.

„ III.—Tin, 54; lead, 34; phosphor copper, 12.
Good lining metal for general work.

An eminent engineer recommends the use of manganese in anti-friction alloys intended for hydraulic machinery, or where chemical solutions give rise to corrosion with the ordinary alloys. He makes three qualities as under:—

No. I.—Tin 16;	lead 3;	cupro-manganese		3.
„ II.—Tin 16;	antimony 2;	„	„	2.
„ III.—Lead 16;	„ 3;	„	„	3.

The following list of anti-friction metals embraces most of the alloys of proved excellence, and, although they have not been put down in the order of their merit, they have been selected from the very best authorities and practice in the engineering world:

Anti-Friction Metals.

Copper.	Tin.	Zinc.	Lead.	Antimony.	Ferro-zinc.	
1	10	..	..	1	..	Babbitt's.
4	82	..	..	14	..	„ No. 2.
1	6	..	..	2	..	„ hardening, 10 % tin added.
4	6	..	..	8	..	Dewrance's.
5	16	79	..	..	..	Fenton's.
..	58½	39½	..	2	..	Parson's.
1	18	..	..	3	..	Roose's.
1	18	..	3	..	..	„ No. 2.
..	46	..	42	12	..	Hoyle's.
4	19	69	5	3	..	Ledebur's.
7½	14½	78	..	..	..	Kingston's.*
4	24	80	..	..	..	Caledonian.
4	18	90	..	..	..	„ No. 2.
2	34	58	6	..	..	
..	5	..	79	16	..	American Car Journals.
1	6	..	80	13	..	Magnolium.
1	3	..	80	16	..	„
4	88	..	..	8	..	American railway.
8	83	..	..	9	..	Tandem.
8	75	..	5	12	..	Plastic metal.
5	85	..	..	10	..	Admiralty metal.
5	82	..	..	13	..	„ „
10	83	..	..	5	2	Plastic metal.
..	..	..	80	15	5	Anti-attrition metal.
..	5	..	76	16	3	„ „ No. 2.
1	94	..	..	5	..	Spinning metal.
3	90	..	..	7	..	„ „ No. 2.
2	67	30	..	1	..	White marine bronze.
2	42	56	..	..	..	„ „ „ No. 2.
8	70	..	10	12	..	„ navy bronze.

* Kingston's original anti-friction metal contained a good percentage of mercury, but this is seldom used now.

ANTI-FRICTION METALS—*continued.*

Copper.	Tin.	Zinc.	Lead.	Anti-mony.	Yellow Metal.	
4	35	..	44	17	..	White navy bronze No. 2
14	60	26	..	..	..	„ brass.
6	30	60	..	4	..	„ „ No. 2.
10	30	60	..	..	..	„ „ No. 3.
..	82	..	9	9	..	„ „ for patterns
4	88	..	..	8	..	
..	53	..	33	10	4	
4	10	85	1	..	..	"Salgee" metal.
..	15	..	68	17	..	"Graphite" „
1	40	..	47	12	..	"Clyde" „
2	63	..	27	8	..	„ „ No. 2.
..	41	..	47	9	3	Barrow „
..	43	..	46	11	..	„ „ No. 2.
12	..	..	80	8	..	Metallic packing.
10	..	..	80	10	..	„ „
..	10	..	70	20	..	„ „ French.
10	..	..	70	20	..	Eccentrics.
..	10	..	60	30	..	Piston rings.
..	30	..	60	10	..	„ „
8	74	..	..	18	..	Hard plastic.
6	70	..	12	12	..	
..	76	..	7	17	..	
3	77	..	17	3	..	
..	38	..	38	24	..	Light machines.
5	40	..	45	10	..	Heavy „
8	82	..	..	10	..	Axle boxes.
6	82	..	..	12	..	Slide valves.
6	14	80	..	..	..	
..	..	47	47	6	..	

ANTI-FRICTION METALS—*continued.*

Phosphor Copper.	Tin.	Zinc.	Lead.	Antimony.	Babbitt's Hardening.	
12	55	..	33	..	..	Durable.
4	84	Bismuth 1		10	..	"Ideal."
..	17	..	58	..	25	
..	34	..	48	..	18	
..	37	..	44	..	19	
	30	..	48	12	10	
Copper. 8	..	91	1	..	..	Fontainmoreau's bronze.
..	18	75	4	3	..	
6	17	77	..	..	..	Solid locomotive bearings.
..	48	48	..	4	..	"Anchor" brand.
11	67	..	..	22	..	
5	35	60	..	..	..	
..	20	..	74	6	..	
1	92	..	..	7	..	"Titanium."
..	74	..	..	26	..	Hard face metre valves.
..	70	..	..	30	..	" " "
1	68	31½	½	..	..	Very tough.

TYPE METAL.

The following are the principal alloys used:

Lead.	Antimony.	Tin.	Copper.	Zinc.	
80	20	..	..	..	Ordinary type.
55	30	15	..	..	French "
55	22½	22½	..	..	English " No. 1.
61·3	18·5	20·7	..	..	" " " 2.
69·2	19·5	9·1	1·7	..	" " " 3.
3	..	4	4	80	Ehrhardt's type.
2	..	3	2	93	" " No. 2.
69	15½	Bismuth 15½		..	Stereotype plates.

WHITE METALS, FUSIBLE METALS AND SOLDERS.

Copper.	Tin.	Zinc.	Lead.	Anti-mony.	Bis-muth.	Cad-mium.	
..	90	..	..	10	..	..	Standard Britannia Metal.
3½	88½	..	..	8	..	..	Queen's metal.
..	..	..	70	15	15	..	Expansion metal.
..	16	..	..	56	28	..	" "
..	26	..	19	..	48	13	Fusible metal, melts at 158° F.
..	12½	..	25	..	50	12½	" " " " 160° F.
..	2	..	..	..	3	1	" " " " 203° F.
..	3	..	2	..	..	..	Solder, melts at 334° F.
..	2	..	1	..	..	..	" " " 340° F.
..	1	..	1	..	..	..	" " " 370° F.
*..	1	..	2	..	..	..	" " " 441° F.
..	1	..	1	..	1	..	Bismuth Solder " " 284° F.

* *Plumbers' Sealed Solder.*

CHAPTER VI.

MISCELLANEOUS ALLOYS AND TABLES.

A BEAUTIFUL violet-coloured alloy is produced by melting together equal parts of antimony and copper: this alloy, however, has not yet been applied to any useful purpose.

An alloy, the electrical resistance of which diminishes with an increase of temperature, is composed of copper, manganese, and nickel. Another alloy, which is practically independent of the temperature, consists of 70 parts of copper combined with 30 parts of ferro-manganese.

A non-oxidisable alloy, containing iron and nickel, is frequently used for concave mirrors, or where speculum metals—taking a high polish and resembling platinum—are desired. Such an alloy consists of iron 10 parts, nickel 36, copper 18, tin 18, and zinc 18.

Marlie's non-oxidisable alloy is of similar composition—iron 10 parts, nickel 35, brass 25, tin 20, zinc 10. Articles prepared from this alloy are heated

to a white heat, and dipped into a mixture of sulphuric acid 60 parts, nitric acid 10, hydrochloric acid 5, water 25.

Another alloy for speculum metal is composed of 32 parts of copper, 15·5 parts of tin, 2 parts of nickel: some arsenic may be advantageously added to this alloy.

*Platinoid.**—This alloy, invented by H. Martino, is a kind of German silver, with an addition of 1 to 2 per cent. of tungsten. The latter, in the form of phosphor-tungsten, is first melted together with a certain quantity of copper, the nickel is next added, then the zinc, and finally the remainder of copper. In order to remove the phosphorus and a portion of the tungsten, both of which separate as dross, the resulting compound is several times remelted. Finally, an alloy of a beautiful white colour is obtained, which, when polished, closely resembles silver, and retains its lustre for a long time. Platinoid has the properties of German silver in a pre-eminent degree. It shows great resistance, which changes but little with the temperature, and is about 1½ times greater than that of German silver.

*Steel Composition.** —Steel shavings 60 parts, copper 22·5, mercury 20, tin 15, lead 7·5, and zinc 15, are gradually introduced and dissolved in 860 parts of nitric acid. The resulting reddish-brown paste is dried, melted together with twenty times its

* Metallic Alloys.

weight of zinc, and the mass cast in ingots. After cooling, the alloy is remelted with a corresponding addition of tin, according to whether it is to be softer or harder.

Another substitute alloy for hardened steel tools requires no tempering or dressing. Castings are simply made, and an edge ground on with an emery wheel. The composition shows both variety and novelty.

	No. 1. For Drills, Chisels, etc.		No. 2. For Cutters, etc.
Cast iron	17·25	..	17·25
Chromium	1·50	..	2·00
Ferro-manganese	3·00	..	4·50
Tungsten	5·25	..	7·50
Aluminium	1·25	..	2·00
Nickel	0·50	..	0·75
Copper	0·75	..	1·00
Wrought iron	70·50	..	65·00

*Bronze Resisting Acids.**—Débié gives the following receipt: copper 15 parts, zinc 2·34, lead 1·82, antimony 1. This alloy, melted in a crucible, can be worked in the ordinary manner, and is claimed to answer as a substitute for lead for lining vessels used in the manufacture of sulphuric acid, etc.

*American Sleigh-Bells.**—These bells, excelling in beauty, fine tone, and small specific gravity, are manufactured by fusing together 10 parts of nickel and 60 of copper. When this alloy has become cold, add 10 parts of zinc and two-fifths part of aluminium, fuse the mass, and allow it to cool; then remelt it with the

* Metallic Alloys.

addition of two-fifths part of mercury and 60 parts of melted copper.

Bismuth Bronze. — Webster's bismuth bronze is made of various proportions. According to the statement of its discoverer, its composition and qualities are as follows: For a hard alloy take 1 part of bismuth and 16 of tin, both by weight, and, having melted them, mix them thoroughly. For a hard bismuth bronze take 69 parts of copper, 21 of spelter, 9 of nickel, and 1 of the above hard alloy of bismuth and tin. This bismuth bronze is a hard, tough, sonorous, metallic alloy, which is proposed for use in the manufacture of screw propeller blades, shafts, tubes, and other appliances employed partially or constantly in sea-water. In consequence of its toughness, it is thought to be well suited for telegraph wires and similar purposes where much stress is borne by the wires. From its sonorous quality it is well adapted for piano wires. For domestic utensils, and articles exposed to atmospheric influences, use bismuth 1 part, aluminium 1, and tin 15, melted together to form the separate or preliminary alloy, which is added in the proportion of 1 per cent. to the above described alloy of copper, spelter and nickel. This bronze forms a bright and hard alloy, suited for the manufacture of utensils or articles exposed to oxidation.

Deoxidised Bronze is a popular metal in some parts of America. The following analysis, by James S. de Benneville, gives its average composition: copper 82·67,

tin 12·40, zinc 3·23, lead 2·14, iron 0·10, silver 0·07, phosphor 0·005.

Aluminium Bronze, patented by J. Jeancon, 1891: copper, 75 to 85 parts; manganese, 2 to 5 parts; aluminium, 12 to 25 parts.

Nickel Steel.—An alloy by Guillimane, which is said to supersede "Platiniridium," is composed of nickel 34 per cent., commercial steel 66 per cent.

The hardest known alloy is made from iron 6 parts, chromium 4 parts.

Engraving Bronze.—An alloy suitable for sign-plates and panels is made by melting 100 parts of copper, and adding in succession 6 parts of magnesium, 57 parts of sal-ammoniac, 18 parts of unslaked lime, and 9 parts of cream of tartar, all pulverised. When this has been accomplished, 15 parts of tin or zinc, as desired, are added to complete the alloy.

Mira Metal.—The alloy known by this name is distinguished by great resistance to acids, and is therefore especially suitable for cocks, pipes, etc., which come into contact with acid liquids. Mira metal contains, according to analysis:

Copper	74·755
Lead	16·350
Iron	0·430
Zinc	0·615
Tin	0·910
Antimony	6·785
Nickel and Cobalt	0·240

CRUCIBLE FURNACES.

Whatever economises labour or material in a workshop is worth having, and in the matter of foundry plant or equipment, a small and seemingly insignificant alteration may have very great results.

Foundry plant has not received the attention of the inventor to any great extent, so there have been few radical changes in moulders' tools and appliances, excepting, perhaps, in the style of flasks and furnaces.

There is a great variety of the latter in the market, suitable for melting brass or steel in crucibles, and in all probability, the most important among the improvements which have come to stay, is what is known as the "caisson" furnace. The simplicity of its arrangement makes us wonder that practical men were so long content to use, and periodically tear down and rebuild, such an antiquated concern as the "all brick pit furnace" for melting metals in crucibles.

Numerous ingenious designs of these caisson crucible furnaces are advertised in America; some of them adapted for natural draught with solid fuel, and others for hot air blast, gas, or oil fuel with forced draught; but for reliable working, and on the score of economy of metal, fuel and crucibles, the majority of brassfounders favour the simple form of caisson furnace with solid fuel—charcoal or coke—and induced draught. It may be seen from the sketches that the only brickwork or masonry required for this kind of furnace is that

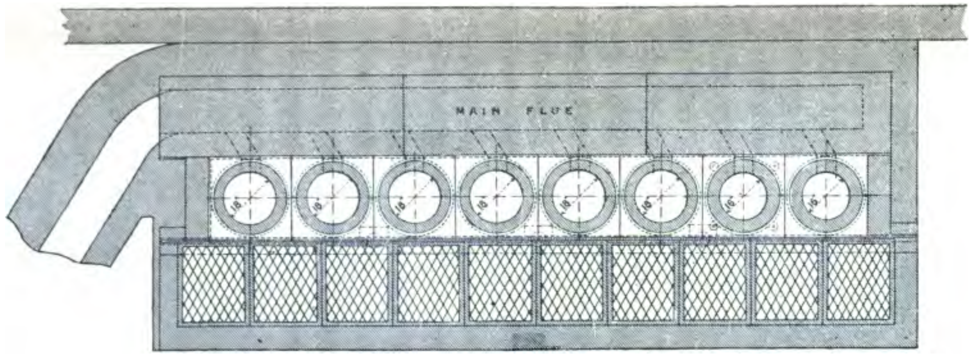

Fig.1.

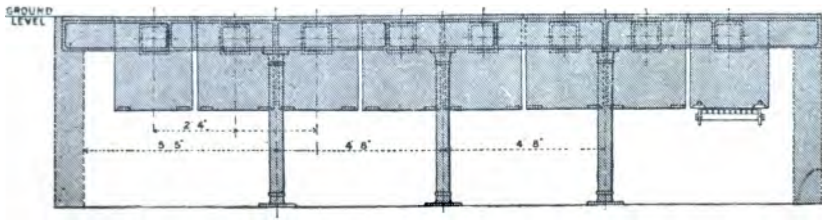

Fig.2.

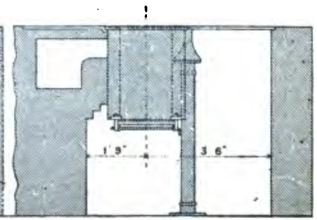

Fig.3.

in the outer walls, the flue, and the lining: the other parts are all cast iron; consequently, there can be no leakage, and the furnace does not "draw air" excepting from the proper source—through the firebars. It is hardly necessary to go into any lengthy description of the construction of the furnace, as it is simply an arrangement of butts and beams. Where a range of

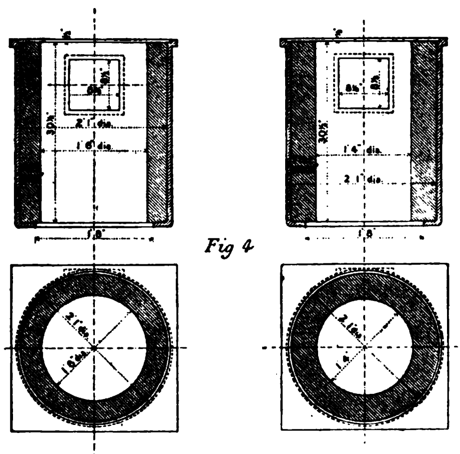

Fig 4

six, eight, or ten furnaces are to be put down, the casings are made to hang upon two longitudinally checked beams—one at the back and one in front—which are supported by pillars at regular intervals.

Fig. 1 is a plan of furnaces in position.

Fig. 2 shows the elevation of the same.

Fig. 3 gives in detail the method of fixing in the supports for the firebars.

Fig. 4 is a section of the casing with firebrick lining.

Then follow the wrought-iron details required to complete the furnace. As provision is made for lifting the casings out, repairs can be done at any time, without interfering with the day's work, by having a spare

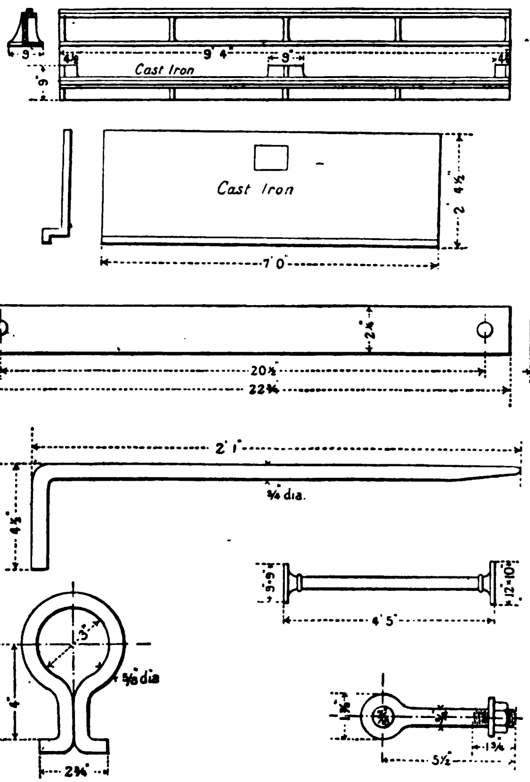

Fig. 5.—Details.

casing cast, and keeping it always ready to take the place of any one that may get out of order.

Firebrick sleeves, as shown in Fig. 5, are sometimes fitted into these caisson furnaces instead of the built firebrick lining. It is usual to leave an air space between the sleeve and the casing; this space may either be left open, or filled in loosely with some non-conducting material. The advantages of these sleeves over the ordinary built lining are many; a considerable saving of time and material in relining is effected. The bottom part of all pit fires burns away much sooner than the top portion, and this necessitates either the repair or the renewal of that part. It is much easier to take out one of these sleeves, when the bottom portion is half worn, turn it upside down, and re-insert in the casing, than it is to cut out the three bottom tiers of a built lining and rebuild, as is often done. For a time the drop-bottom grating took the place of loose firebars in these furnaces, but because they were more expensive, and caused inconvenience if one got damaged, they have been discarded in many places.

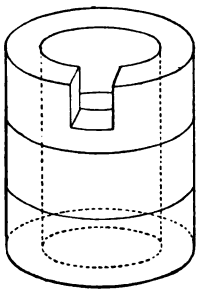

Fig. 6.

All the text-books on metallurgy advocate the use of charcoal dust, powdered glass, borax, or some such covering, to render the molten metal impervious to the

oxidising influence of the air, but unfortunately, in ordinary brassfoundry practice, these excellent preventives are seldom used. The best flux for brass is potash sulphate, i.e. sal-enixum and charcoal mixed, and a good mixture for preventing porosity in brass alloys is composed of 2 parts of green-bottle glass (powdered) and 1 part manganese dioxide. Furnacemen as a class don't study text-books much; but by repeatedly melting alloys, they soon acquire a practical knowledge of the difficulties to be encountered, and although they may not understand the theory of oxidation, they have methods of their own to prevent it, and the loss ensuing from it. A good furnaceman can be distinguished at once by his firing methods. He brings his fire up to a good heat before charging, has a solid bottom, say 4 inches deep, for the crucible to sit upon, and he carries the fire right over the top of the crucible, so that as the bottom wears away, and the char or coke eases down the sides, there is always a protective covering of charcoal over the surface of the metal being melted. A furnace charged in this way needs no pokering or looking after for an hour, and 200 lbs. of metal can be melted without blast or forced draught of any kind in about two hours. An unskilled furnaceman, again, is always pottering about the furnaces, poker in hand, and taking the cover off occasionally to see if the metal has "gone down," thereby giving himself unnecessary trouble, losing time and heat in the melting of the metal, and exposing it to an inrush of fresh air.

A Revolving Ingot-Mould.*

The sketch represents a new design of an ingot-mould, which possesses many advantages over the regular flat-pattern in every-day use. First, it obviates the use of tongs when emptying hot ingots; second, it saves space, twenty ingots only occupying the space of ten of the ordinary pattern; third, it does not draw damp, being raised from the ground; fourth, with a series of these ingot-moulds a heat of metal can be poured and emptied in much less time, thereby saving waste of metal through oxidisation. The two ends *E E* are of mild steel flattened batswing shape on one end, and cast into the ingot-moulds which are supported on two trestles with flat checks wide enough to allow for the turnover of the ingot. At *H* there is a $\frac{5}{8}$-inch hole for the pin *P* with which the ingot-mould is canted over.

Fig. 7.—Pin.

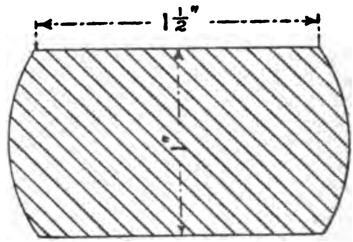

Fig. 8.—Section of Ends.

* 'Feilden's Magazine,' July 1900.

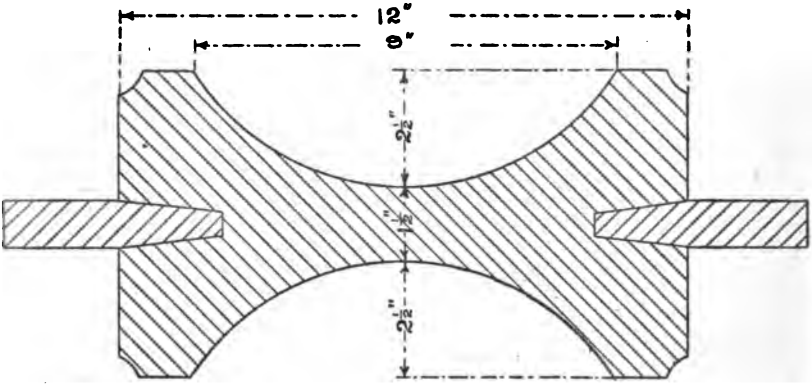

Fig. 9—Section of Ingot-Mould.

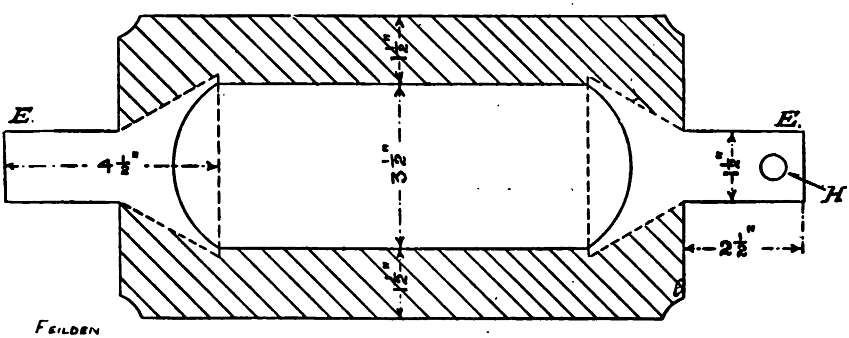

Fig. 10—Top View.

PROPERTIES OF USEFUL METALS AND ALLOYS.

Metal.	Specific Gravity.	Tensile Strength per sq. in. in tons.	Elongation per cent.	Weight of 1 cub. in. in lbs.	Shrinkage of Castings.
Aluminium (cast)	2·56	6	3	·092	$\frac{17}{64}$″
„ (No. 6 forged)	..	13	6	..	..
„ Bronze 10 %	7·65	30	22	..	$\frac{1}{4}$″
„ Brass 2 %	8·33	31·28	30	..	$\frac{3}{16}$″
Antimony	6·72	..	..	·242	..
Bismuth	9·82	..	..	·35	$\frac{5}{32}$″
Brass 70/30 %	8·44	13½	65	·307	$\frac{3}{16}$″
„ 67/33 %	8·30	12½	..	..	..
„ 63/37 %	8·23	21	28	..	$\frac{5}{32}$″
Naval brass (rolled)	8·48	27	20	..	..
Muntz Metal 60/40 %	8·20	28	42	..	..
Copper (cast)	8·8	14	7	·32	$\frac{3}{16}$″
Delta metal	8·0	34	26	·3	..
Iron (cast)	7·21	8	0·5	·263	$\frac{1}{8}$″
„ (forged)	7·78	22	15	·279	$\frac{1}{10}$″
Steel (cast)	7·8	35	13	·282	$\frac{5}{32}$″
„ (mild)	7·7	32	16	..	..
Gun bronze 88.10.2	8·56	16	13	·308	$\frac{3}{16}$″
Phosphor bronze	8·5	17	10	..	..
Manganese „	8·25	41	24	·304	..
Lead	11·4	1	..	·41	$\frac{5}{16}$″
Tin (cast)	7·29	2	..	·263	$\frac{1}{4}$″
Zinc (cast)	7·0	..	..	·253	$\frac{5}{16}$″

Castings are sold by the pound, and the various metals are bought in by the hundredweight or ton.

This table is handy for converting the price per pound to hundredweights or tons, or for comparing the price of metals bought and sold. In fixing prices, a farthing

Comparative Table in Prices.

Per lb.	Per cwt.			Per ton.			Per lb.	Per cwt.			Per ton.		
d.	£	s.	d.	£	s.	d.	d.	£	s.	d.	£	s.	d.
¼	0	2	4	2	6	8	6¼	2	18	4	58	6	8
½	0	4	8	4	13	4	6½	3	0	8	60	13	4
¾	0	7	0	7	0	0	6¾	3	3	0	63	0	0
1	0	9	4	9	6	8	7	3	5	4	65	6	8
1¼	0	11	8	11	13	4	7¼	3	7	8	67	13	4
1½	0	14	0	14	0	0	7½	3	10	0	70	0	0
1¾	0	16	4	16	6	8	7¾	3	12	4	72	6	8
2	0	18	8	18	13	4	8	3	14	8	74	13	4
2¼	1	1	0	21	0	0	8¼	3	17	0	77	0	0
2½	1	3	4	23	6	8	8½	3	19	4	79	6	8
2¾	1	5	8	25	13	4	8¾	4	1	8	81	13	4
3	1	8	0	28	0	0	9	4	4	0	84	0	0
3¼	1	10	4	30	6	8	9¼	4	6	4	86	6	8
3½	1	12	8	32	13	4	9½	4	8	8	88	13	4
3¾	1	15	0	35	0	0	9¾	4	11	0	91	0	0
4	1	17	4	37	6	8	10	4	13	4	93	6	8
4¼	1	19	8	39	13	4	10¼	4	15	8	95	13	4
4½	2	2	0	42	0	0	10½	4	18	0	98	0	0
4¾	2	4	4	44	6	8	10¾	5	0	4	100	6	8
5	2	6	8	46	13	4	11	5	2	8	102	13	4
5¼	2	9	0	49	0	0	11¼	5	5	0	105	0	0
5½	2	11	4	51	6	8	11½	5	7	4	107	6	8
5¾	2	13	8	53	13	4	11¾	5	9	8	109	13	4
6	2	16	0	56	0	0	1/-	5	12	0	112	0	0

is usually accepted as the minimum fraction. Any lesser fractions are arranged for by graduated discounts.

TABLE SHOWING METALS IN THE ORDER OF MALLEABILITY, DUCTILITY, TENACITY.

Malleability.	Ductility.	Tenacity.
Gold	Platinum	Iron
Silver	Silver	Copper
Copper	Iron	Platinum
Tin	Copper	Silver
Lead	Gold	Zinc
Zinc	Aluminium	Gold
Platinum	Zinc	Tin
Iron	Tin	Lead
	Lead	

The metals in an alloy nearly always give characteristic fractures and colorations by which they can be distinguished, and with the aid of a good magnifying glass a freshly broken sample will reveal to the trained brassfounder whether it contains an admixture of tin, lead, antimony, etc.; of course only a rough estimate can be formed in this way, but it is generally near enough for buying or blending purposes.

In the best brassfoundry practice it is customary to make a small sample of any new or untried alloy before using it for castings, and, when scrap enters into the

composition, the advantages of this preliminary alloy are obvious.

Formal specifications invariably state alloys in parts —centesimally,—and very often test bars of the specified alloy are demanded before permission to proceed with the castings is obtained. The table given below will be found convenient for turning parts into pounds whenever small quantities for samples or test bars are required.

TABLE FOR CONVERTING SIMPLE PARTS INTO AVOIRDUPOIS EQUIVALENTS.

Parts.	lbs.	Parts.	lbs.	Parts.	lbs.	Parts.	lbs.	Parts.	lbs.
16 =	1	33 =	$2\frac{1}{16}$	50 =	$3\frac{1}{8}$	67 =	$4\frac{3}{16}$	84 =	$5\frac{1}{4}$
17 =	$1\frac{1}{16}$	34 =	$2\frac{1}{8}$	51 =	$3\frac{3}{16}$	68 =	$4\frac{1}{4}$	85 =	$5\frac{5}{16}$
18 =	$1\frac{1}{8}$	35 =	$2\frac{3}{16}$	52 =	$3\frac{1}{4}$	69 =	$4\frac{5}{16}$	86 =	$5\frac{3}{8}$
19 =	$1\frac{3}{16}$	36 =	$2\frac{1}{4}$	53 =	$3\frac{5}{16}$	70 =	$4\frac{3}{8}$	87 =	$5\frac{7}{16}$
20 =	$1\frac{1}{4}$	37 =	$2\frac{5}{16}$	54 =	$3\frac{3}{8}$	71 =	$4\frac{7}{16}$	88 =	$5\frac{1}{2}$
21 =	$1\frac{5}{16}$	38 =	$2\frac{3}{8}$	55 =	$3\frac{7}{16}$	72 =	$4\frac{1}{2}$	89 =	$5\frac{9}{16}$
22 =	$1\frac{3}{8}$	39 =	$2\frac{7}{16}$	56 =	$3\frac{1}{2}$	73 =	$4\frac{9}{16}$	90 =	$5\frac{5}{8}$
23 =	$1\frac{7}{16}$	40 =	$2\frac{1}{2}$	57 =	$3\frac{9}{16}$	74 =	$4\frac{5}{8}$	91 =	$5\frac{11}{16}$
24 =	$1\frac{1}{2}$	41 =	$2\frac{9}{16}$	58 =	$3\frac{5}{8}$	75 =	$4\frac{11}{16}$	92 =	$5\frac{3}{4}$
25 =	$1\frac{9}{16}$	42 =	$2\frac{5}{8}$	59 =	$3\frac{11}{16}$	76 =	$4\frac{3}{4}$	93 =	$5\frac{13}{16}$
26 =	$1\frac{5}{8}$	43 =	$2\frac{11}{16}$	60 =	$3\frac{3}{4}$	77 =	$4\frac{13}{16}$	94 =	$5\frac{7}{8}$
27 =	$1\frac{11}{16}$	44 =	$2\frac{3}{4}$	61 =	$3\frac{13}{16}$	78 =	$4\frac{7}{8}$	95 =	$5\frac{15}{16}$
28 =	$1\frac{3}{4}$	45 =	$2\frac{13}{16}$	62 =	$3\frac{7}{8}$	79 =	$4\frac{15}{16}$	96 =	6
29 =	$1\frac{13}{16}$	46 =	$2\frac{7}{8}$	63 =	$3\frac{15}{16}$	80 =	5	97 =	$6\frac{1}{16}$
30 =	$1\frac{7}{8}$	47 =	$2\frac{15}{16}$	64 =	4	81 =	$5\frac{1}{16}$	98 =	$6\frac{1}{8}$
31 =	$1\frac{15}{16}$	48 =	3	65 =	$4\frac{1}{16}$	82 =	$5\frac{1}{8}$	99 =	$6\frac{3}{16}$
32 =	2	49 =	$3\frac{1}{16}$	66 =	$4\frac{1}{8}$	83 =	$5\frac{3}{16}$	100 =	$6\frac{1}{4}$

Equivalents of Pounds Avoirdupois.

lb.	10		100			1000				10,000				100,000			
	qr.	lb.	cwt.	qr.	lb.	ton	cwt.	qr.	lb.	ton	cwt.	qr.	lb.	ton	cwt.	qr.	lb.
1	0	10	0	3	16	0	8	3	20	4	9	1	4	44	12	3	12
2	0	20	1	3	4	0	17	3	12	8	18	2	8	89	5	2	24
3	1	2	2	2	20	1	6	3	4	13	7	3	12	133	18	2	8
4	1	12	3	2	8	1	15	2	24	17	17	0	16	178	11	1	20
5	1	22	4	1	24	2	4	2	16	22	6	1	20	223	4	1	4
6	2	4	5	1	12	2	13	2	8	26	15	2	24	267	17	0	16
7	2	14	6	1	0	3	2	2	0	31	5	0	0	312	10	0	0
8	2	24	7	0	16	3	11	1	20	35	14	1	4	357	2	3	12
9	3	6	8	0	4	4	0	1	12	40	3	2	8	401	15	2	24

Example.—Find weight in tons, etc., equivalent to 7520 lb.

	tons	cwt.	qr.	lb.
7000 lb. =	3	2	2	0
500 lb. =	0	4	1	24
20 lb. =	0	0	0	20
7520 lb. =	3	7	0	16

INDEX.

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